

Second Design Review
SURFACE VEHICLE NAVIGATION STUDY (SVNS)
September 1979 to September 1980

Sponsored by
Frank Weinchel, Vice President
General Motors Technical Center
Warren, Michigan

Performed by
Rockwell-Collins
Avionics Advanced Technology
Avionics and Missiles Group
Cedar Rapids, Iowa

Steve F. Russell, Project Manager

In January of 1979, I transferred from the NAVSTAR GPS (GDM) program to the Advanced Technology Department of the Avionics and Missiles Group. It was a promotion step toward becoming a Principal Engineer. I wanted the freedom to work on a variety of projects instead of just one or two. I still continued my support of the GDM program and was heavily involved in its success.

For a year or more I had been talking to Rockwell leadership about transferring our military technology to the realm of civil applications of GPS. Primarily, I had in mind that we would develop GPS for civil aviation and automobiles. There was understandable resistance to the idea because our business expertise was military, not civil. However, the head of our advanced technology department, Norbert Hemesath, believed in the idea and began looking for an outside sponsor for a design and trade-off study for civil applications of GPS. He found support for the idea from Frank Weinchel, VP at General Motors.

GM funded us at a level of \$840K/yr (2010 dollars) and we launched the SVNS project with a team of 7 engineers with varied expertise to do the trade-off study. This report summarized the majority of our work and was created to inform GM as to the feasibility of putting a system in Cadillacs. My colleagues soon nicknamed the project 'CADNAV'.

Although I was the Project Manager, my instincts as a design engineer still drove me to participate in the system and function design as much as I could. I am especially happy to have had the time to develop the system concept represented in the diagram in this report. It was a logical extension of my experience on the GDM program.

There were many memorable moments on this project but none were more memorable than the trip to Warren, Michigan to present the progress report to Frank Weinchel; and the technical meetings with Wes Rogers and Jim Laggan. The minute I

arrived at the GM Tech Center, I was ushered into a room and given instructions on how I was to conduct myself, what I was to say and details on Frank's personality. You don't often encounter these issues in day-to-day engineering! I swear the following is exactly what happened. My Instructions were as follows:

1. Frank has an ulcer so we will not be serving alcohol at the meeting.
2. Don't mention anything about project problems to Frank.
3. Jim Laggan (my technical counterpart) will not be in the meeting because GM has a rule about how many levels of management can be in a room at the same time and Frank ranks too high for Jim to be in the meeting.

It was a whole new world as compared to the very formal engineering environment at Rockwell.

I left Rockwell-Collins for King Radio in August of 1980 and did not get to see the project to its completion. However, it was put into the very capable hands of my colleague, Jurgen Bruckner who did a great job of completing it.

Steve F. Russell
Project Manager, SVNS

REFERENCE: Memo, SVNS-12, March 21, 1980

Here is a list of the names of people I remember from that project:

Loren DeGroot
Norbert Hemesath
Robert 'Bob' Pool
'Ab' Mayer
Dave Cunningham
Robert 'Bob' Jaycox
John 'Jack' Murphy
Lew Nigra
Jurgen Bruckner
Ken Brown
Eugene 'Gene' Frye
Robert 'Wade' Walstrom
Howard Rooks

SVNS DISTRIBUTION

2ND Design Review

§

SVNS PROGRAM Review

Date: 21- MARCH- 1980

Memo: SVNS-12

X GROUP-1

____ L. E. DeGroot 107-142
____ N. B. Hemesath 124-222
____ R. H. Pool 124-222
____ A. F. Mayer 106-180
____ D. L. Cunningham 107-142
____ R. L. Jaycox 107-141
(2) ____ S. F. Russell 124-222
____ J. W. Murphy 107-142

GROUP-2

X ____ L. M. Nigra 106-180
____ H. M. Schweighofer 124-222
____ J. M. Bruckner 124-222
____ M. H. Rhodes 106-187
____ K. L. Brown 106-176
X ____ E. O. Frye 124-222
X ____ R. W. Walstrom 124-222
X ____ P. L. Roberts 107-142

GROUP-3

____ H. B. Rooks 106-176
____ J. A. Martin 106-176
____ J. W. Donaldson 106-176

GROUP-4

____ G. Griffith 107-142
____ W. K. McCune 124-222
____ N. K. Garnatz 120-123

Internal Letter



Rockwell International

Date: • 21 March 1980

No: .

TO: (Name, Organization, Internal Address)

• Distribution

•

•

FROM: (Name, Organization, Internal Address, Phone)

• S. F. Russell

• 124-222

• X4911

•

Subject: • SVNS Program Review

A program review for the SVNS study for GM was held in Warren, Michigan on Friday, March 14. A copy of the view cell handout is enclosed.

The purpose of the meeting was to inform the GM Tech Center VP, Frank Weinchel, of the status of the study. A secondary purpose was to discuss technical details with Wes Rogers and Jim Laggan. The schedule and manning view cells and the cost estimates on page 2,20 were not shown. Also, the Engineering Design Review (Section III) was not presented or discussed. Wes Rogers has informed me that he and Jim Laggan will present a written response to Section III.

The meeting was quite unproductive from a technical standpoint but did produce positive results about our effort and possible future work.

S. F. Russell
Project Manager

SFR/ljp
Attachment

SURFACE VEHICLE NAVIGATION SYSTEM

PROGRAM REVIEW

14 MARCH 1980

**ROCKWELL INTERNATIONAL
AVIONICS AND MISSILES GROUP**

I, NAVSTAR PROGRAM STATUS

AGENDA

- I. NAVSTAR PROGRAM STATUS
- II. EXECUTIVE SUMMARY
- III. ENGINEERING DESIGN REVIEW

3-14-80

SVNS PROGRAM REVIEW

II. EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

AGENDA

A. INTRODUCTION

B. PROGRAM OVERVIEW

C. MINIMUM-COST DESIGN

D. MINIMUM-COST DESIGN APPROACH

- | | |
|------------------------|---|
| 1) SVNS SYSTEM CONCEPT | 4) MAJOR HARDWARE COST ELEMENTS |
| 2) BASELINE DEFINITION | 5) COST AND PERFORMANCE TRADE-OFF STUDIES |
| 3) ENGINEERING REVIEW | 6) RISK AREAS |

E. ALTERNATE FUNCTIONAL DESIGNS

F. COST PREDICTIONS

G. TECHNICAL SUMMARY

INTRODUCTION

PROGRAM OVERVIEW

- PRINCIPLE OBJECTIVE
- STUDY OUTPUT
- STUDY OVERVIEW



**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

PRINCIPLE OBJECTIVE

DEFINE A GPS-BASED SVNS WHICH:

- 1) MEETS ALL OF GM'S OPERATIONAL AND PERFORMANCE REQUIREMENTS
FOR VEHICULAR USE AND**
- 2) HAS THE POTENTIAL TO ACHIEVE THE STRINGENT COST GOALS
ATTENDANT TO THE AUTOMOTIVE MARKET,**

A. OPERATIONAL REQUIREMENTS

B. PERFORMANCE REQUIREMENTS

C. COST GOALS

D. AUTOMOTIVE APPLICATION





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

STUDY OUTPUT

A REPORT WHICH DOCUMENTS IN AS MUCH DETAIL AS NECESSARY:

- | | |
|--|--|
| 1) OVERALL SYSTEM ARCHITECTURE | 5) TECHNICAL RISK AREAS |
| 2) SYSTEM OPERATIONAL PROCEDURES
AND CONCEPTS | 6) ESTIMATED MANUFACTURING
COST |
| 3) PACKAGING CONCEPTS | 7) COST RISK AREAS |
| 4) DEVICE AND DISPLAY TECHNOLOGIES | 8) ESTIMATED DEVELOPMENT COSTS |

A. SYSTEM DEFINITION

B. TECHNOLOGY

C. COST

D. RISK

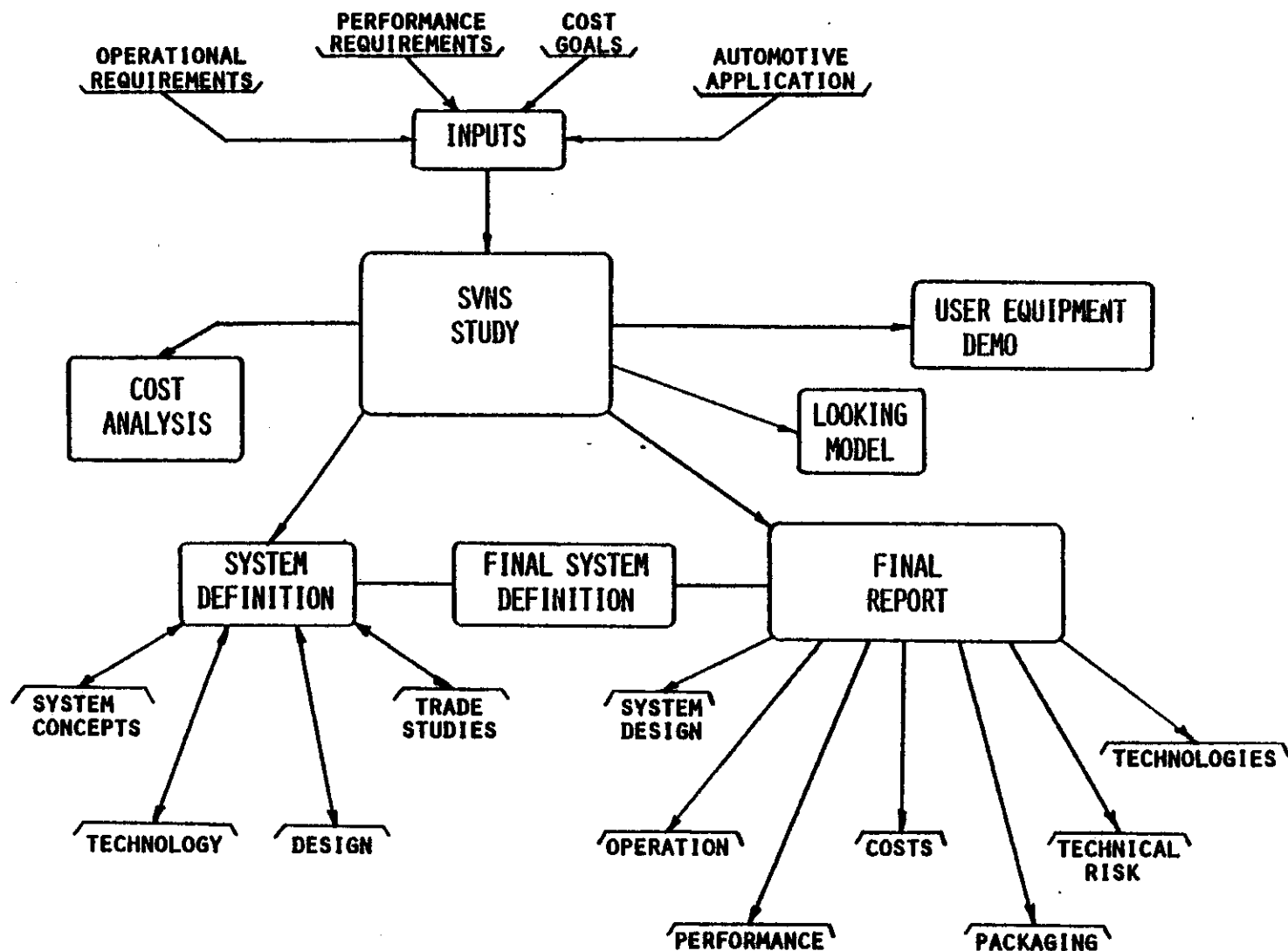
E. FINAL REPORT





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

STUDY OVERVIEW





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

MINIMUM-COST DESIGN

- **A HIGHLY ITERATIVE PROCESS INVOLVING MANY COST VS
PERFORMANCE TRADE-OFF STUDIES**
- **COMPLETE CHARACTERIZATION OF MOST PROMISING
CANDIDATE DESIGNS**
- **SUMMARY OF DESIGNS**
 - COST
 - PERFORMANCE
 - RISK
 - SIZE
 - WEIGHT
 - POWER
- **CUSTOMER SELECTION OF "BEST" DESIGN**





**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

MINIMUM-COST DESIGN APPROACH

- **DEFINE SYSTEM CONCEPT**
- **DEVELOP SEVERAL CANDIDATE FUNCTIONAL DESIGNS**
- **IDENTIFY COSTLY FUNCTIONS**
- **CHOOSE A BASELINE DESIGN FOR COMPLETE EVALUATION**
 - **BASELINE DEFINITION**
 - **SYSTEM LEVEL ENGINEERING REVIEW**
 - **LOW-COST DESIGN CYCLE**
 - **RISK ASSESSMENT**
 - **FINAL DEFINITION**
- **REVIEW BASELINE DESIGN FOR PRODUCT FEASIBILITY**
- **CHOOSE AN ALTERNATE FUNCTIONAL DESIGN FOR COMPLETE EVALUATION**
- **SUMMARIZE ALL PROMISING DESIGNS**
- **SELECT "BEST" DESIGN**

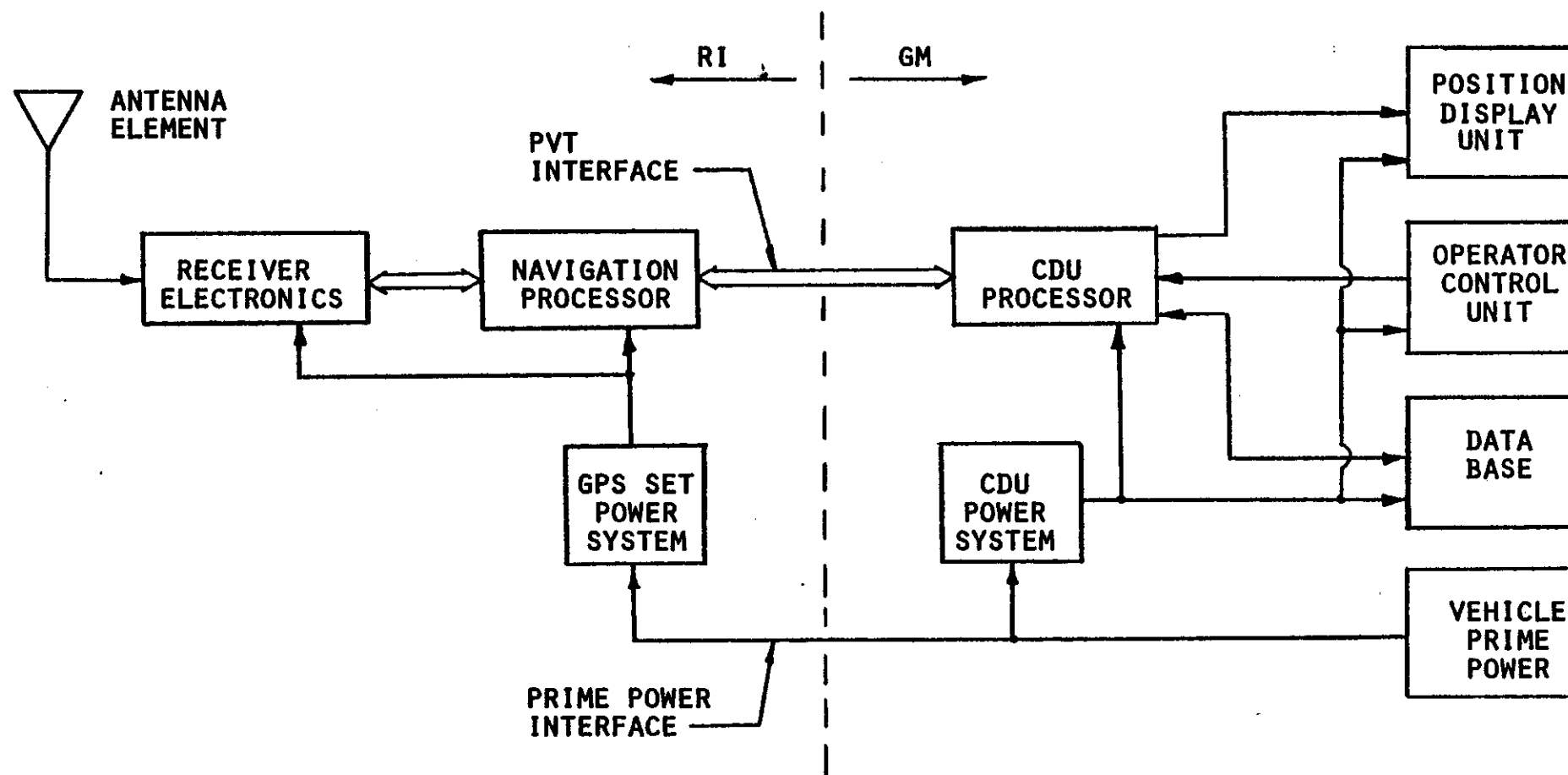




SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

MINIMUM-COST DESIGN APPROACH

SVNS SYSTEM CONCEPT





**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

BASELINE DEFINITION

BASELINE DESIGN CONSIDERATIONS

MANPACK

- **L1 AND L2**
 - L1-L2 4x2 SWITCH
 - IONOSPHERIC CORRECTION
 - 10 MHZ CODE GEN
- **C/A AND P CODES**
 - COMPLEX HARDWARE SLEW CIRCUITS
 - WIDEBAND IF
- **HIGH ANTI-JAM**
 - PROMPT CHANNEL
 - DELAY-LOCK TRACKING
 - T-CODE PREVENTS JAMMER FEEDTHRU
 - 2 CODE MULTIPLIERS
 - FAST AGC
- **HIGH ACCURACY**
 - CARRIER PHASE TRACK
 - SLOW SEQUENCE
- **HIGH STABILITY FREQ STD**
- **RADIATION HARDENING**

SVNS

- **L1 ONLY**
 - NO SWITCH
 - NO CORRECTION
 - 1 MHZ CODE GEN
- **C/A ONLY**
 - NO SLEWING
 - NARROWBAND IF
- **NO HOSTILE JAMMING**
 - NO PROMPT CHANNEL
 - TAU-DITHER TRACKING
 - NO T-CODE
 - ONE CODE MULTIPLIER
 - NO PULSE JAMMING
- **MODERATE ACCURACY**
 - CARRIER FREQUENCY TRACK
 - FAST SEQUENCE
- **MIN DESIGN FREQ STD**
- **NO RADIATION HARDENING**

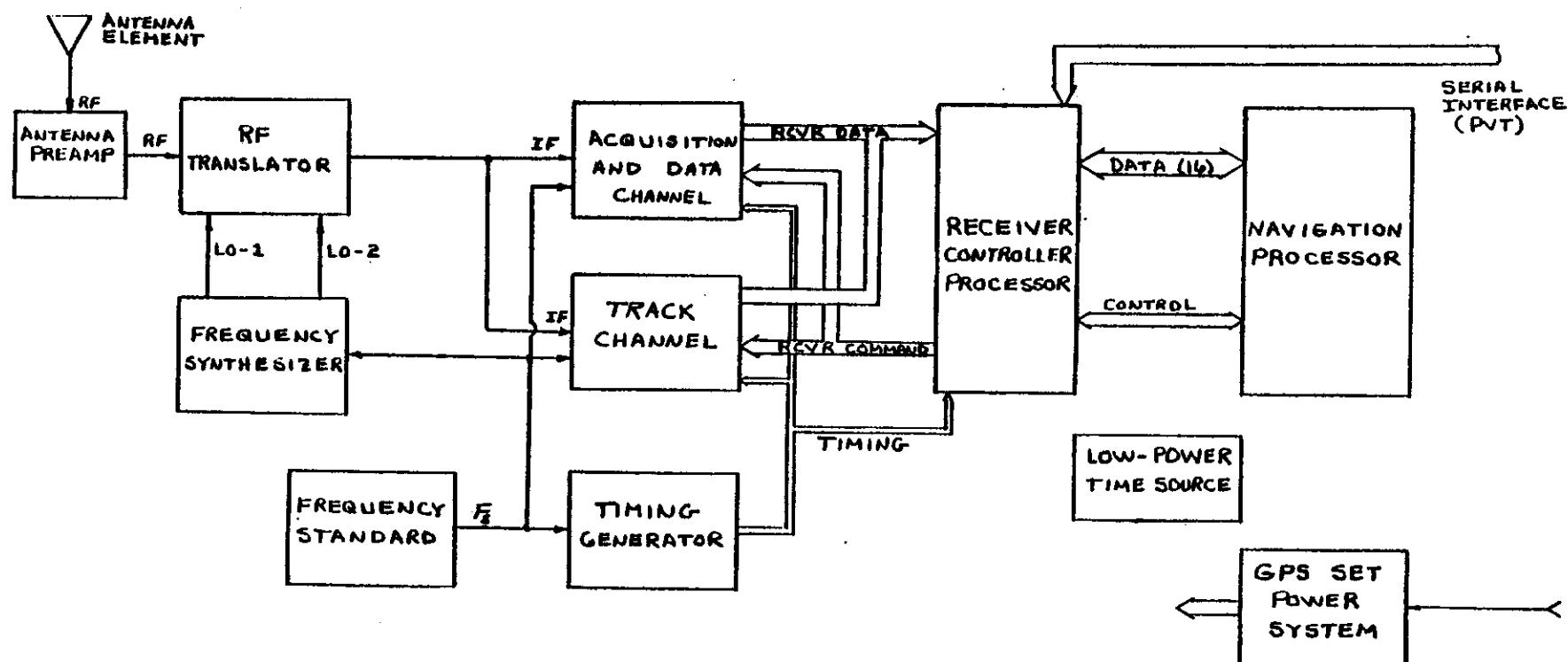




SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

BASELINE DEFINITION

BASELINE FUNCTIONAL BLOCK DIAGRAM





**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

SYSTEM LEVEL ENGINEERING REVIEW

- **VERIFY ADHERENCE TO SYSTEM CONCEPT**
- **TEST VALIDITY OF BASELINE DESIGN**
- **PROBE FOR MAJOR DESIGN FLAWS**
- **RECOMMENDATION OF FUNCTIONAL CHANGES**
- **"GO AHEAD" FOR LOW-COST DESIGN CYCLE**



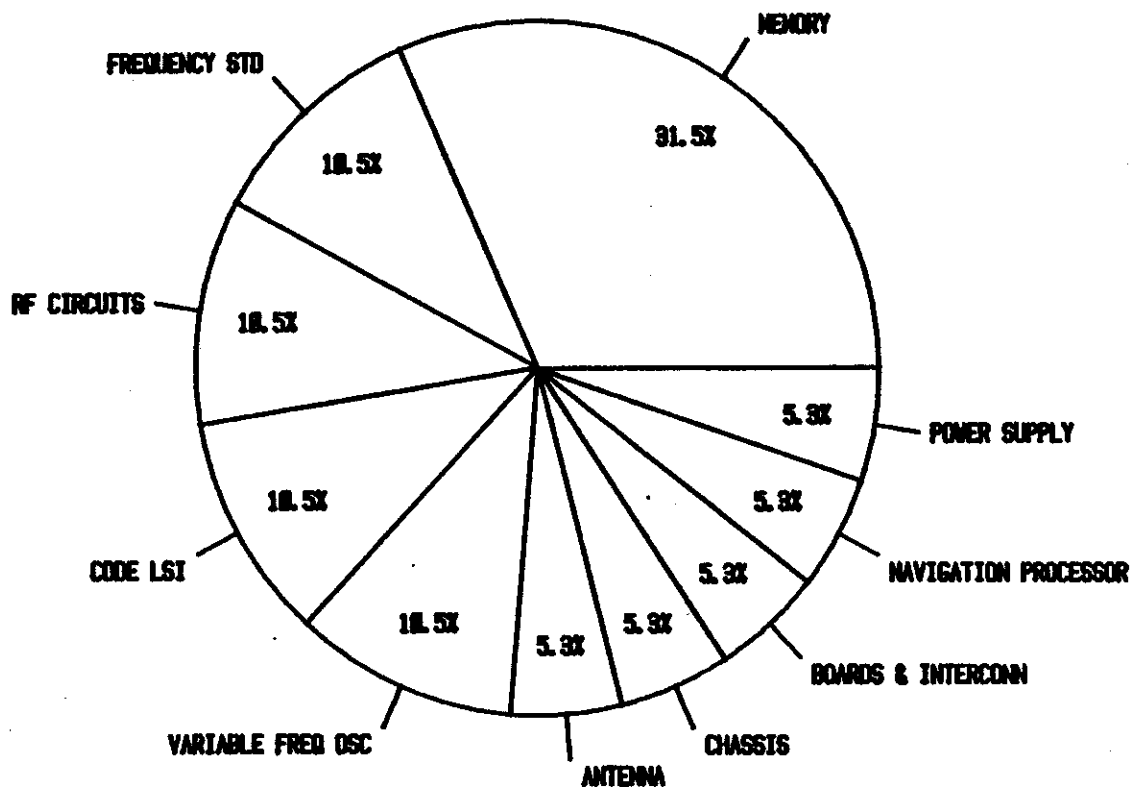


SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

LOW-COST DESIGN CYCLE

MAJOR HARDWARE COST ELEMENTS

- FREQUENCY STANDARD
- VARIABLE FREQUENCY OSC
- CODE LSI
- RF CIRCUITS
- POWER SUPPLY
- NAVIGATION PROCESSOR
- MEMORY
- BOARDS & INTERCONNECT
- CHASSIS
- ANTENNA





**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

LOW-COST DESIGN CYCLE

COST AND PERFORMANCE TRADE-OFF STUDIES

● **PRESENT**

- ANTENNA
- FREQUENCY STANDARD
- VARIABLE FREQUENCY OSCILLATORS
- FREQUENCY PLAN
- DATA DEMODULATOR

● **FUTURE**

- CUSTOM LSI
- MEMORY DENSITY, TECHNOLOGY, POWER, SPEED, COST
- NAVIGATION PROCESSOR SELECTION
- SINGLE OR DUAL CHANNEL
- MECHANICAL DESIGN
- POWER SUPPLY





**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

LOW-COST DESIGN CYCLE

FINAL COST DETERMINATION

- **COMPLETE TRADE-OFF STUDIES**
- **COMPLETE BASELINE MECHANICAL DESIGN**
- **REPLACE LOW-VOLUME ESTIMATES WITH HIGH-VOLUME MANUFACTURING**





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

RISK AREAS

- **MEMORY COST**
- **CUSTOM LSI COST & PERFORMANCE**
- **FREQUENCY STANDARD STABILITY**
- **MP THRUPUT**
- **ONE-BIT CODE POSITION DETECTOR**
- **ANTENNA COST**





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

BASELINE FINAL DEFINITION

- **DEPENDENT UPON:**
 - **COMPLETION OF LOW-COST DESIGN CYCLE**
 - **HIGH VOLUME PARTS AND PRODUCTION COST ESTIMATES**
 - **RISK ASSESSMENT**

BASELINE FINAL REVIEW

- **ENGINEERING REVIEW OF FINAL DESIGN**
- **CUSTOMER REVIEW OF COST AND DESIGN**
- **DETERMINE ACCEPTABILITY OF COST, PERFORMANCE, AND DESIGN**
- **SPECIFY NEW COST, PERFORMANCE, AND DESIGN GOALS AS DEVIATIONS
FROM BASELINE**
- **REVIEW ALTERNATE FUNCTIONAL DESIGNS AND ASSESS PROBABILITIES OF
MEETING NEW GOALS**





**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

ALTERNATE FUNCTIONAL DESIGN CHOICES

- **DIGITAL CORRELATOR**
- **SINGLE CHANNEL SEQUENTIAL**
- **NONVOLATILE ELECTRONICALLY ERASABLE PROM**
- **LOW-POWER PROCESSOR**
- **SAW RESONATOR OSCILLATOR**
- **DIRECT CONVERSION RECEIVER**
- **MULTIPLEXED CODE GENERATOR**
- **POWER SUPPLY**





**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

COST PREDICTIONS

PRESENT CONFIDENCE LEVEL	CONFIDENCE GOAL	GPS SENSOR COST
99%	--	\$12K
95%	--	5K
80%	99%	3K
50%	95%	2K
30%	80%	1K
5%	50%	.5K

**MOST PROBABLE
COST RANGE
\$1K - 3K**





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

TECHNICAL SUMMARY

- **MINIMUM-COST DESIGN APPROACH YIELDS BEST COST VS
PERFORMANCE TRADE-OFF**
- **MOST PROBABLE COST RANGE FOR THE GPS SENSOR IS
\$1K - 3K**
- **BASELINE DESIGN NOW IN LOW-COST DESIGN CYCLE**
- **ALTERNATE FUNCTIONAL DESIGNS COMPROMISE PERFORMANCE
FOR LOWER COST**
- **ACTUAL COST ESTIMATE REQUIRES GM ASSISTANCE IN
LEARNING HIGH-VOLUME PARTS COSTS AND PRODUCTION
TECHNIQUES**



III, ENGINEERING DESIGN REVIEW

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SVNS PROGRAM REVIEW

ENGINEERING DESIGN REVIEW

AGENDA

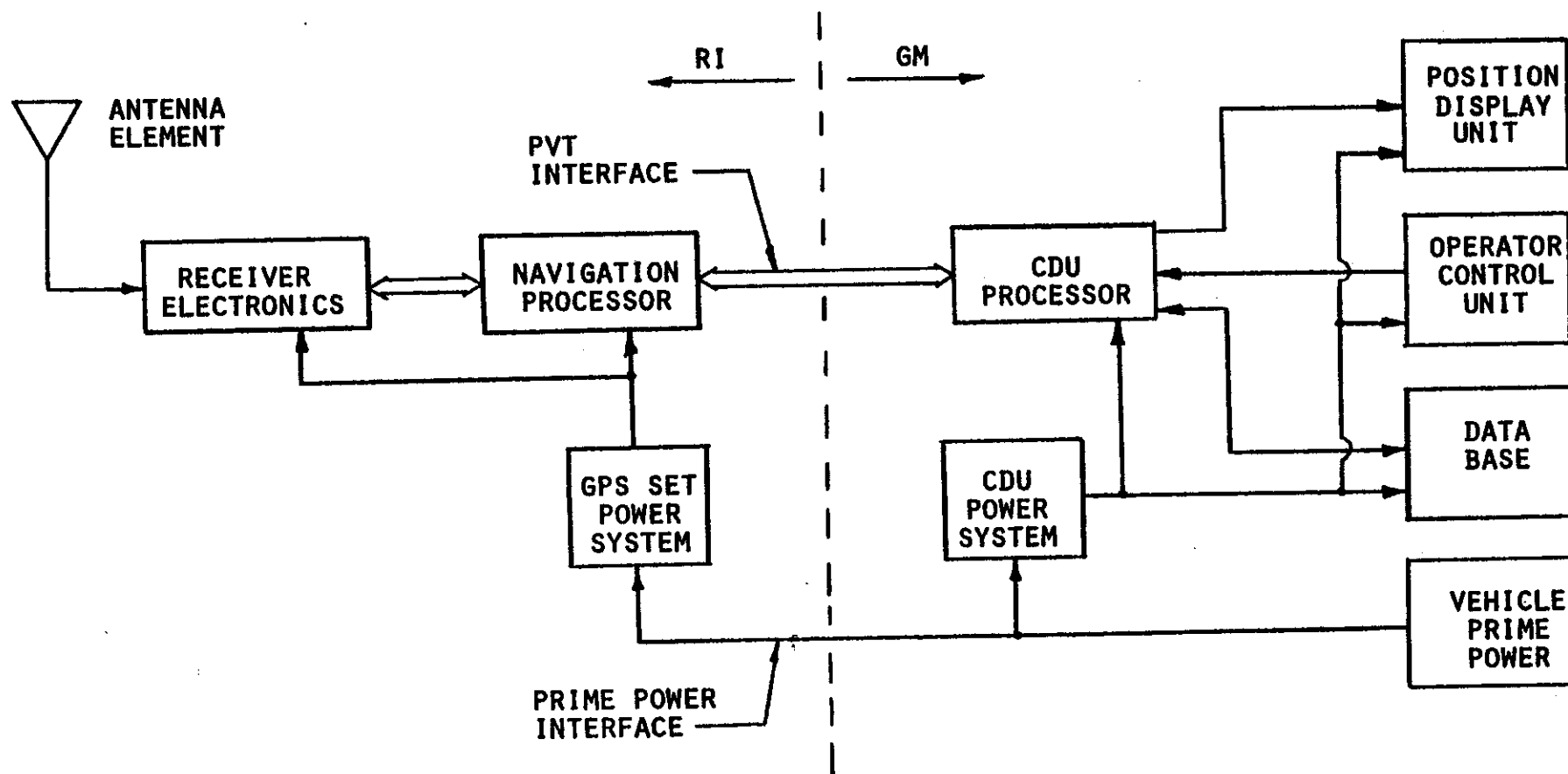
- SVNS SYSTEM CONCEPT
- MINIMUM-COST DESIGN APPROACH
- BASELINE DEFINITION
 - DESIGN CONSIDERATIONS
 - FUNCTIONAL BLOCK DIAGRAM
 - DETAILED RECEIVER BLOCK DIAGRAM
- SYSTEM LEVEL ENGINEERING REVIEW
- MAJOR HARDWARE COST ELEMENTS
- ENVIRONMENTAL REQUIREMENTS
- COST AND PERFORMANCE TRADE-OFF STUDIES
 - PRECISION FREQUENCY STANDARD
 - VCXO AND DIGITAL CARRIER VFO DESIGNS
 - ANTENNA ELEMENT DESIGNS
 - POWER SUPPLY
- COST ANALYSIS
 - COST ESTIMATING
 - HARDWARE DESIGN EXAMPLE
- CUSTOM LSI DESIGN
 - CANDIDATES
 - TRADE-OFFS
 - CODE GENERATOR LOGIC
 - CHIP SIZE COMPARISONS
 - LSI PARTITIONING
 - DIGITAL CARRIER VFO
- PRELIMINARY SIZE AND POWER ESTIMATES
- FINAL COST DETERMINATION
- RISK AREAS
- BASELINE DESIGN COMPLETION
- ALTERNATE FUNCTIONAL DESIGN CHOICES
- TECHNICAL SUMMARY
- FINAL REPORT OUTLINE



SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

MINIMUM-COST DESIGN APPROACH

SVNS SYSTEM CONCEPT





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

DESIGN-TO-COST APPROACH

- DEVELOP A BASELINE SYSTEM
 - ELECTRICAL, INTERCONNECT, CHASSIS
 - REASONABLE COST AND RISK
 - MEET MOST PERFORMANCE* GOALS
- PERFORM TRADE-OFF STUDIES
 - COST
 - RISK
 - PERFORMANCE*

} — FIND THE "KNEE OF THE CURVE"
- CHOOSE MINIMUM COST ALTERNATIVES THAT MEET ACCEPTABLE PERFORMANCE* AND RISK
- UPDATE BASELINE
 - ELECTRICAL, INTERCONNECT, CHASSIS
 - COST AND RISK
 - PERFORMANCE*
- EVALUATE NEW SYSTEM FOR OVERALL FEATURES
- ITERATE UNTIL DESIGN HAS CUSTOMER APPROVAL

* IT IS DIFFICULT TO ASSESS COST VS TECHNICAL PERFORMANCE





**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

BASELINE DEFINITION

BASELINE DESIGN CONSIDERATIONS

MANPACK

- L1 AND L2
 - L1-L2 4x2 SWITCH
 - IONOSPHERIC CORRECTION
 - 10 MHZ CODE GEN
- C/A AND P CODES
 - COMPLEX HARDWARE SLEW CIRCUITS
 - WIDEBAND IF
- HIGH ANTI-JAM
 - PROMPT CHANNEL
 - DELAY-LOCK TRACKING
 - T-CODE PREVENTS JAMMER FEEDTHRU
 - 2 CODE MULTIPLIERS
 - FAST AGC
- HIGH ACCURACY
 - CARRIER PHASE TRACK
 - SLOW SEQUENCE
- HIGH STABILITY FREQ STD
- RADIATION HARDENING

SVNS

- L1 ONLY
 - NO SWITCH
 - NO CORRECTION
 - 1 MHZ CODE GEN
- C/A ONLY
 - NO SLEWING
 - NARROWBAND IF
- NO HOSTILE JAMMING
 - NO PROMPT CHANNEL
 - TAU-DITHER TRACKING
 - NO T-CODE
 - ONE CODE MULTIPLIER
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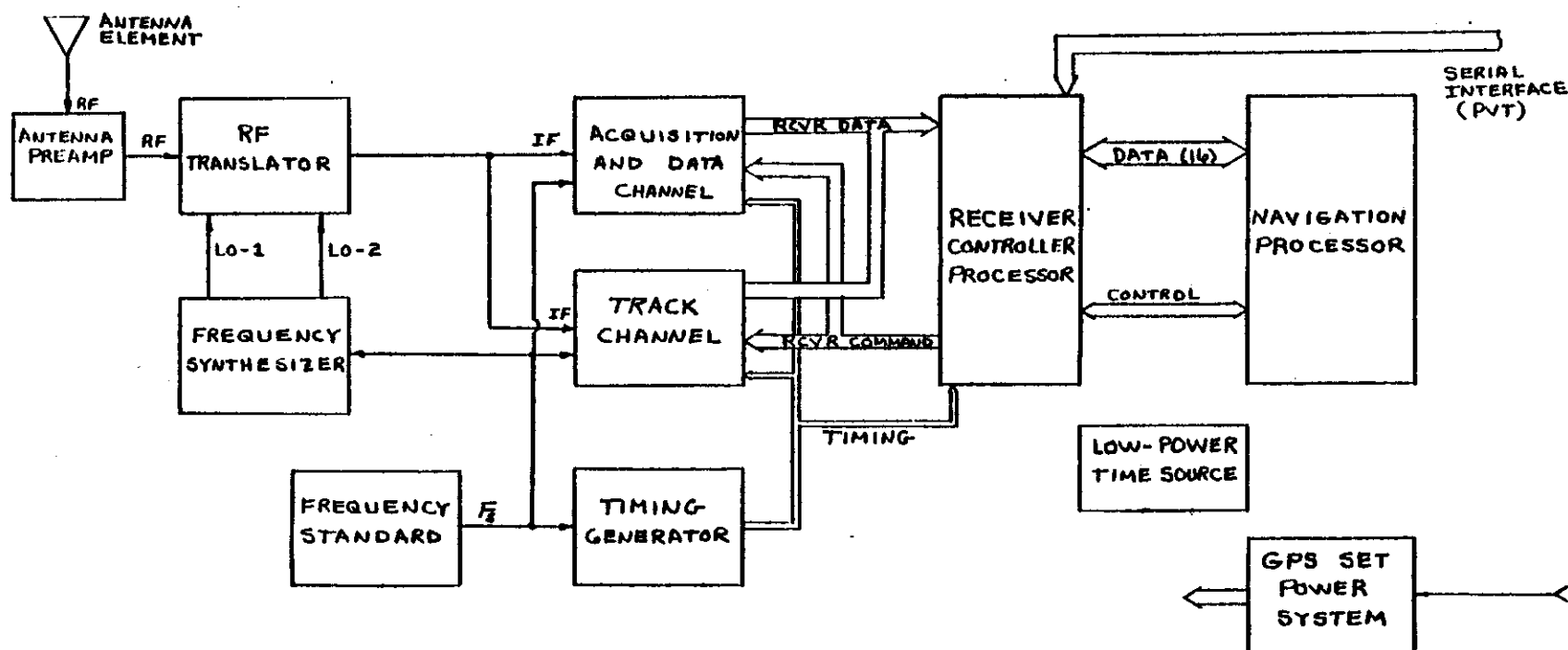


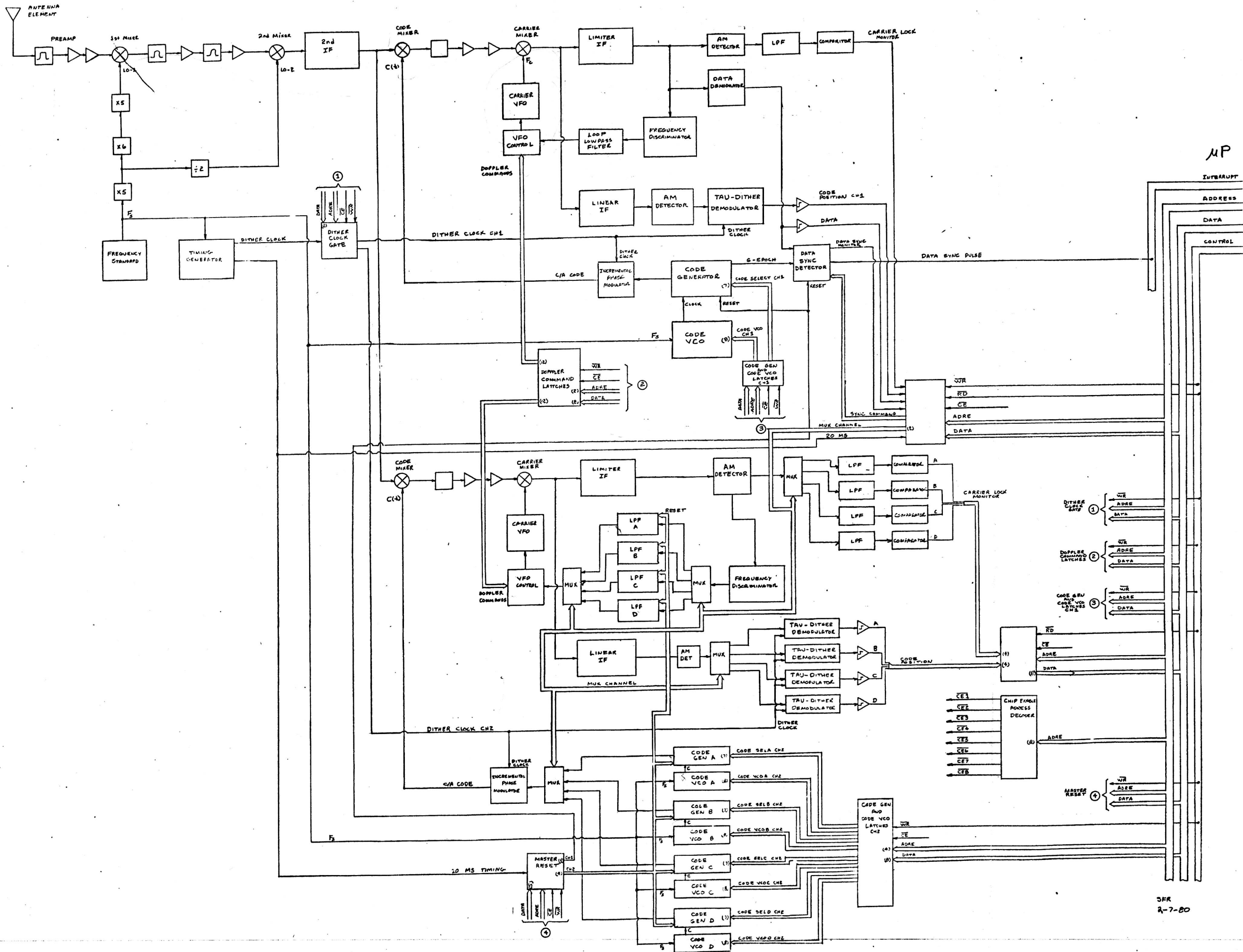


SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

BASELINE DEFINITION

BASELINE FUNCTIONAL BLOCK DIAGRAM







**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

SYSTEM LEVEL ENGINEERING REVIEW

- REVIEW IS COMPLETE
- PRESENT BASELINE SATISFIES SYSTEM CONCEPT
- ALL FUNCTIONS IN BASELINE ARE FEASIBLE
 - DATA DEMOD IS A NOVEL DESIGN BUT TECHNICALLY VALID
 - MULTIPLE CODE VCO OBVIATES SEVERE RESET LOGIC PROBLEM
 - DUAL CHANNELS ALLOW CONTINUOUS TRACKING
 - TWO PROCESSOR CONCEPT ALLOWS LOWER SPEEDS
 - FREQUENCY TRACKING SIMPLIFIES HARDWARE
- NO DESIGN FLAWS FOUND
- LOW-COST DESIGN CYCLE EFFORT APPROVED



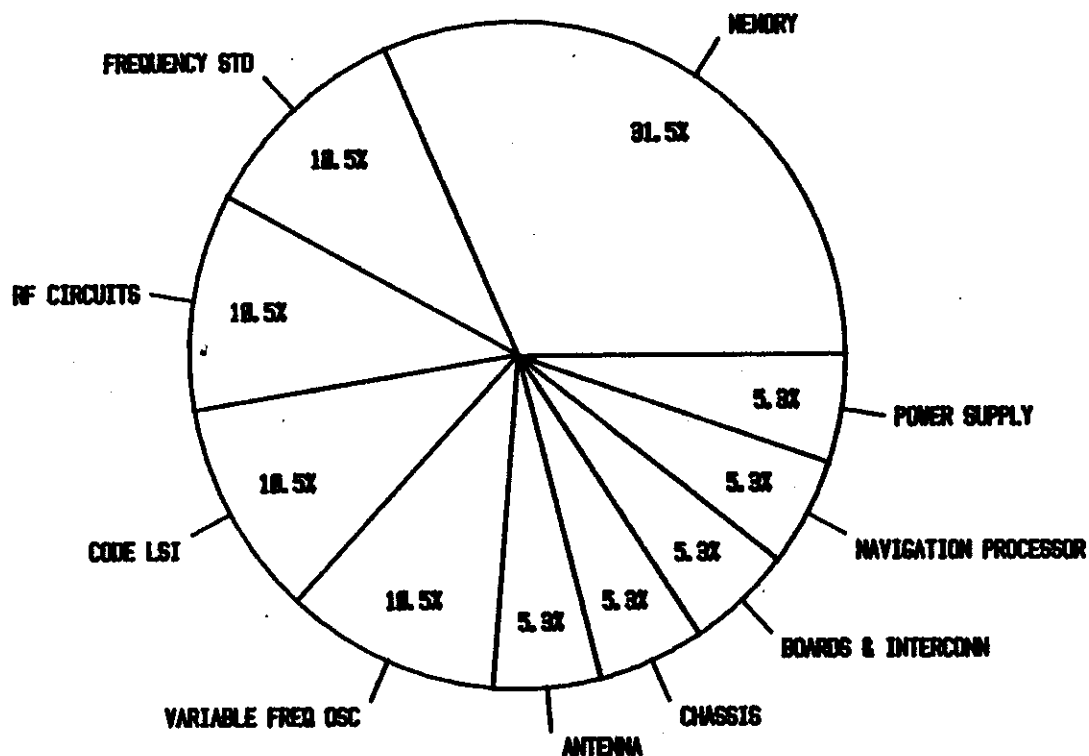


SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

LOW-COST DESIGN CYCLE

MAJOR HARDWARE COST ELEMENTS

- FREQUENCY STANDARD
- VARIABLE FREQUENCY OSC
- CODE LSI
- RF CIRCUITS
- POWER SUPPLY
- NAVIGATION PROCESSOR
- MEMORY
- BOARDS & INTERCONNECT
- CHASSIS
- ANTENNA



ENVIRONMENTAL CONSIDERATIONS FOR TRUNK MOUNTED

SVNS RECEIVER

ENVIRONMENTAL REQUIREMENT	GM ENVIRONMENTAL SPECIFICATION	REMARKS
Temperature	3.5, 3.6	-40°C to +85°C extremes, must pass thermal shock test
Humidity	4.	98% @ 38°C, 80% @ 66°C, frost
Immersion	N.A.	Standing water on floor possible
Shock	6.	48" drop test seems quite severe for sophisticated electronics
Vibration	7.1 - 7.5	Resonance dwells until fatigue failure, 10 ⁶ cycles, or eight hours, whichever occurs first, Seems severe
Salt Spray	N.A.	A standing saturated salt solution is possible on the floor
Sand & Dust	N.A.	A heavy build-up of sand and dust is probable
Oils & Chemicals	N.A.	Spillage of all chemicals listed in SAE J1211, Section 4.4 is possible

NOTE: All tests are described in GM document "Environmental Specification for Electronic Systems", dated 6-13-73.



**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

COST AND PERFORMANCE TRADE-OFF STUDIES

<u>STUDY</u>	<u>STATUS</u>
1. FREQUENCY STANDARD	COMPLETE
2. CARRIER VFO	COMPLETE EXCEPT COST AND RISK
3. FREQUENCY PLAN	COMPLETE EXCEPT SPURIOUS ANALYSIS
4. CODE VCO	COMPLETE
5. CUSTOM LSI	STARTED
6. ANTENNA	COMPLETE EXCEPT COST
7. POWER SUPPLY	STARTED
8. DATA DEMODULATOR	COMPLETE
9. MEMORY SELECTION	STARTED (NMOS CANDIDATE)
10. PROCESSOR SELECTION	STARTED (8086 CANDIDATE)
11. SINGLE VS DUAL CHANNEL	NOT STARTED
12. MECHANICAL DESIGN	CANDIDATES AND ALTERNATIVES IDENTIFIED





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

FREQUENCY STANDARD TRADE-OFFS

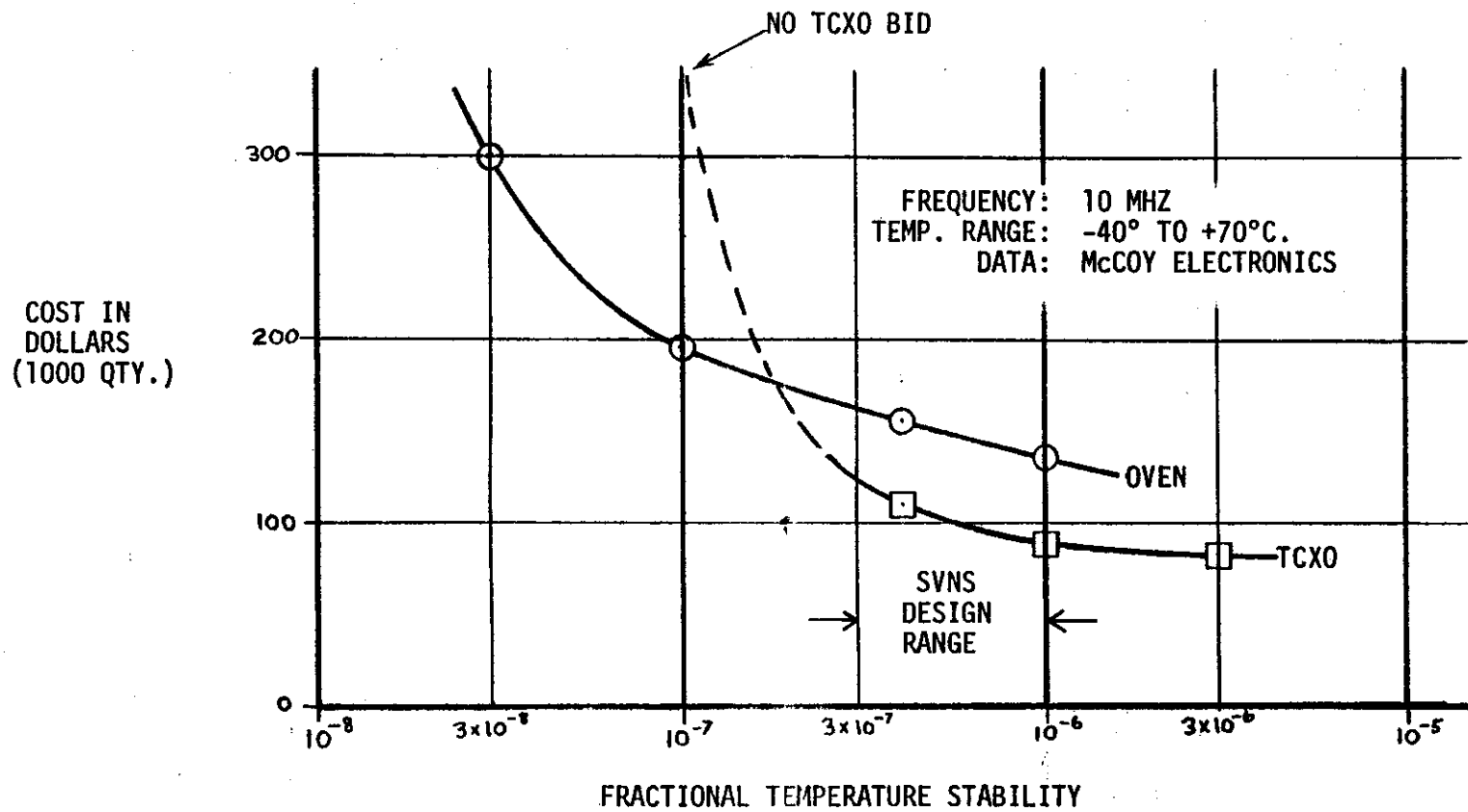
- LARGE FREQUENCY VARIATIONS WITH TEMPERATURE CAUSE LONG ACQUISITION TIMES.
- TEMPERATURE STABILITY IS DRIVING FACTOR IN COST.
- OVENIZED OSCILLATOR REQUIRES HIGH POWER (3-6W) AND LONG WARM-UP TIME (5-10 MIN.).
- TCXO REQUIRES LITTLE POWER (200 MW) AND HAS QUICK WARM-UP (10 SEC.).
- CAN SUFFICIENT STABILITY BE OBTAINED AT LOW COST?
- CAN TCXO BE USED?





SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY

FREQUENCY STANDARD COST VS. STABILITY





SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY

FREQUENCY STANDARD TRADE-OFF RESULTS

- BASELINE TARGET - 1 PPM TCXO.
 - LOW COST, PAST "KNEE" OF CURVE
 - ACQUISITION TIME NOT EXCESSIVE

- ONLY RELATIVE COSTS AVAILABLE.

- COST FOR HIGH-VOLUME AUTOMATED PRODUCTION NOT KNOWN.



VCXO AND DIGITAL
CARRIER VFO DESIGNS

3,15

3-14-80

SVNS PROGRAM REVIEW



SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

CARRIER VFO TRADE-OFFS

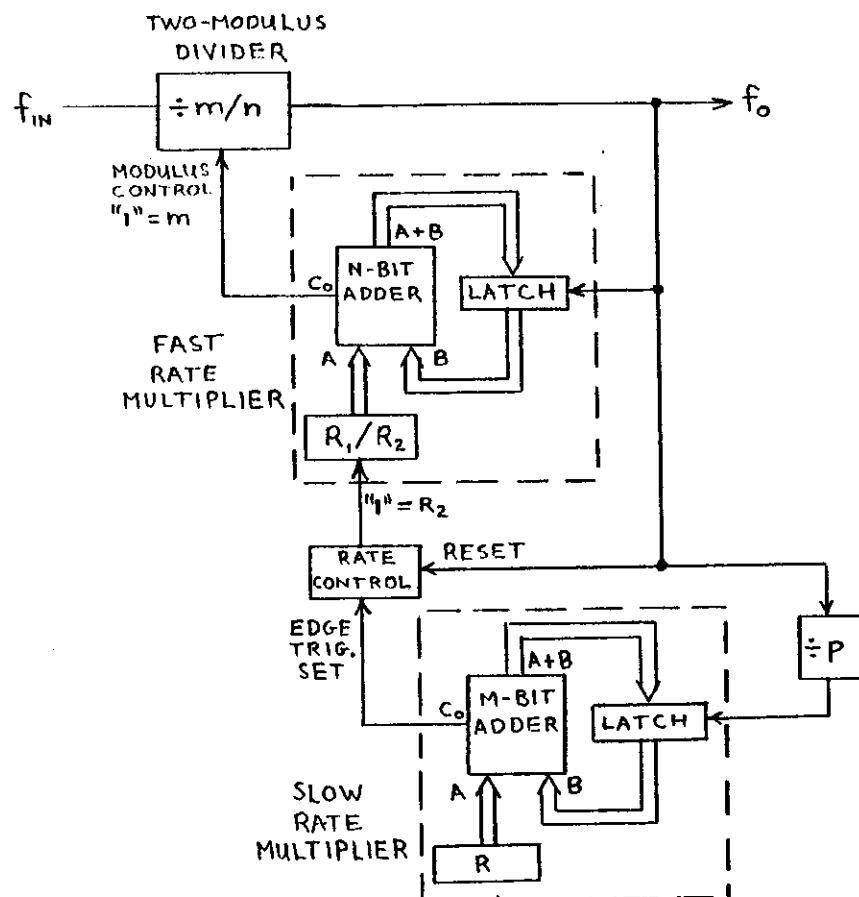
- CARRIER MUST BE TRACKED BY PLL OR AFC.
- DIGITAL VFO (RATE MULTIPLIER VFO) VS. VCXO.
- WHAT IMPACT DOES EACH HAVE ON FREQUENCY PLAN?
- WHAT IS INVOLVED IN VFO CONTROL CIRCUITRY?
- HOW DOES VCXO "SETABILITY" IMPACT COST?
- WHAT IS COST FOR EACH?





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

DIGITAL FREQUENCY GENERATION



A. SINGLE RATE MULTIPLIER (ASSUME FAST RATE = R_1)

- Value in accumulator increases by R_1 on each cycle of f_0 , generating R_1 carries for every 2^N cycles of f_0 .
- When carry occurs, modulus is changed to m .
- In 2^N cycles of f_0 there will be R_1 counts of m and $(2^N - R_1)$ counts of n , yielding an average count of:

$$\bar{c} = \frac{R_1 m + (2^N - R_1)n}{2^N} = \frac{R_1}{2^N} (m - n) + n$$

- The average count will be between n and m .

B. DUAL RATE MULTIPLIER

- Slow rate multiplier increments once every P cycles of f_0 and generates R carries every 2^M cycles of f_0 .
- When slow accumulator generates a carry, fast rate changes to R_2 on a "one-shot" basis.
- As a result, fast rate multiplier will generate slightly more carries if R_2 is larger than R_1 , and less if R_2 is smaller than R_1 .
- The average count for the dual rate multiplier can be shown to be:

$$\bar{c} = n + \frac{R_1}{2^N} (m - n) + \frac{R}{2^M} \frac{(R_2 - R_1) (m - n)}{2^N P}$$





**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

VCXO AND DIGITAL VFO PERFORMANCE CONTRASTS

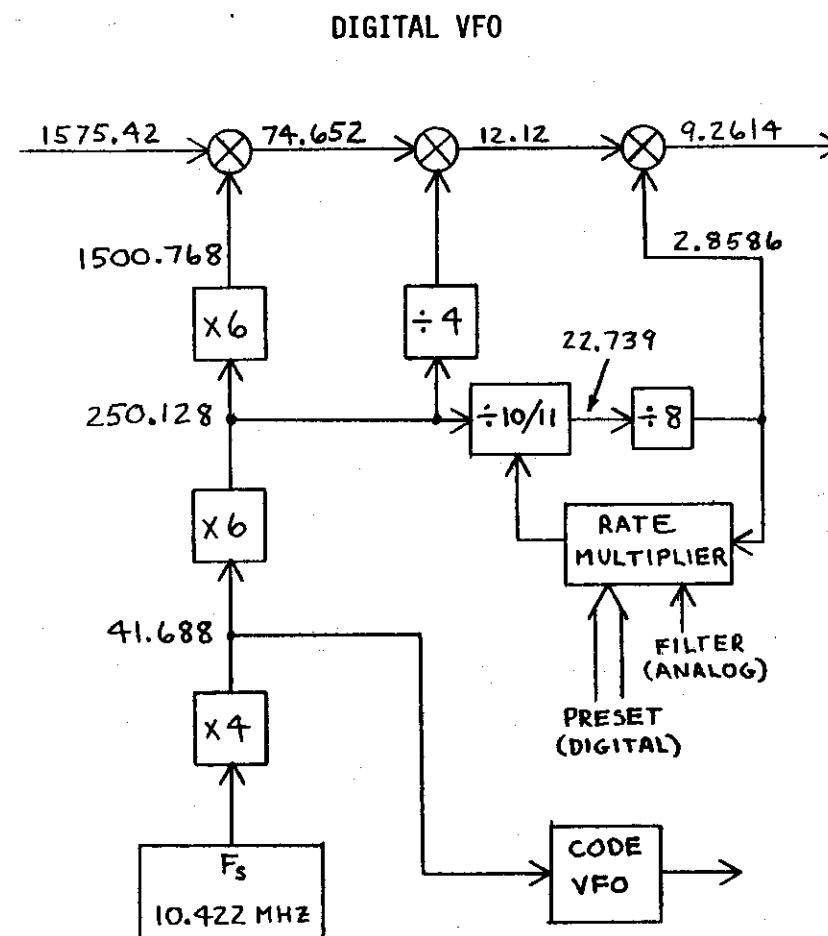
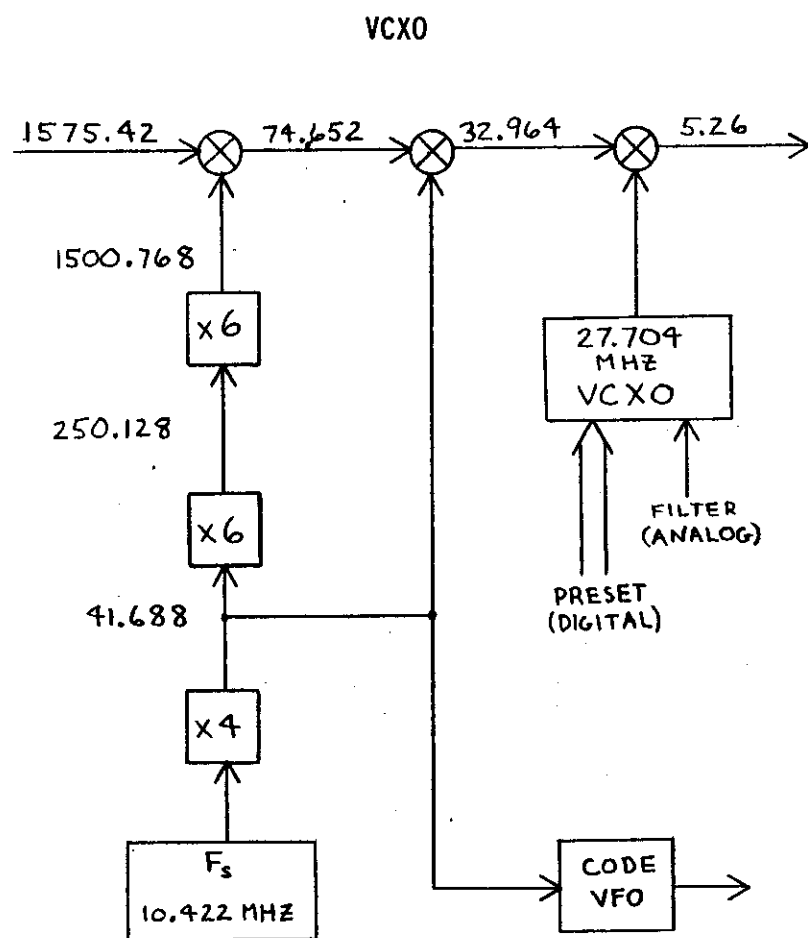
	<u>VCXO</u>	<u>DIGITAL VFO</u>
LINEARITY	DIFFICULT TO OBTAIN	ANALYTICALLY PREDICTABLE NON-LINEARITY
STABILITY	DIFFICULT TO OBTAIN	DETERMINED SOLELY BY REFERENCE
DIGITAL PRESET	REQUIRES HIGH-ACCURACY D/A	DIRECT
ANALOG FILTER INPUT	DIRECT	REQUIRES LOW-ACCURACY A/D
SUPPLY VOLTAGE(S)	MAY REQUIRE + AND - VOLTAGE, OR + VOLTAGE GREATER THAN 10V	SINGLE +5V SUPPLY
POWER	LOW - APPR. 100 MW.	HIGH - .5 TO 1 WATT
OUTPUT FREQUENCY	CONTINUOUSLY VARIABLE	DISCRETE
SPECTRAL PURITY	SPURIOUS-FREE	MANY SPURIOUS OUTPUTS
CUSTOM LSI	NOT APPLICABLE	YES





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

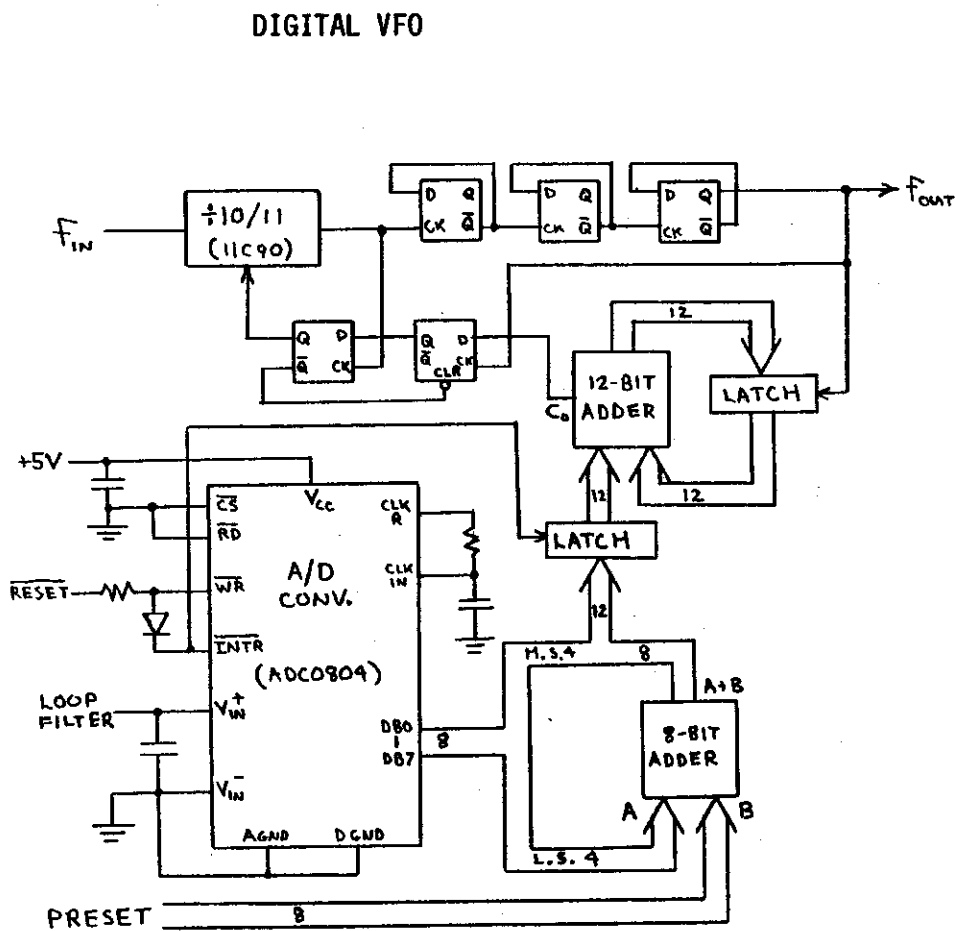
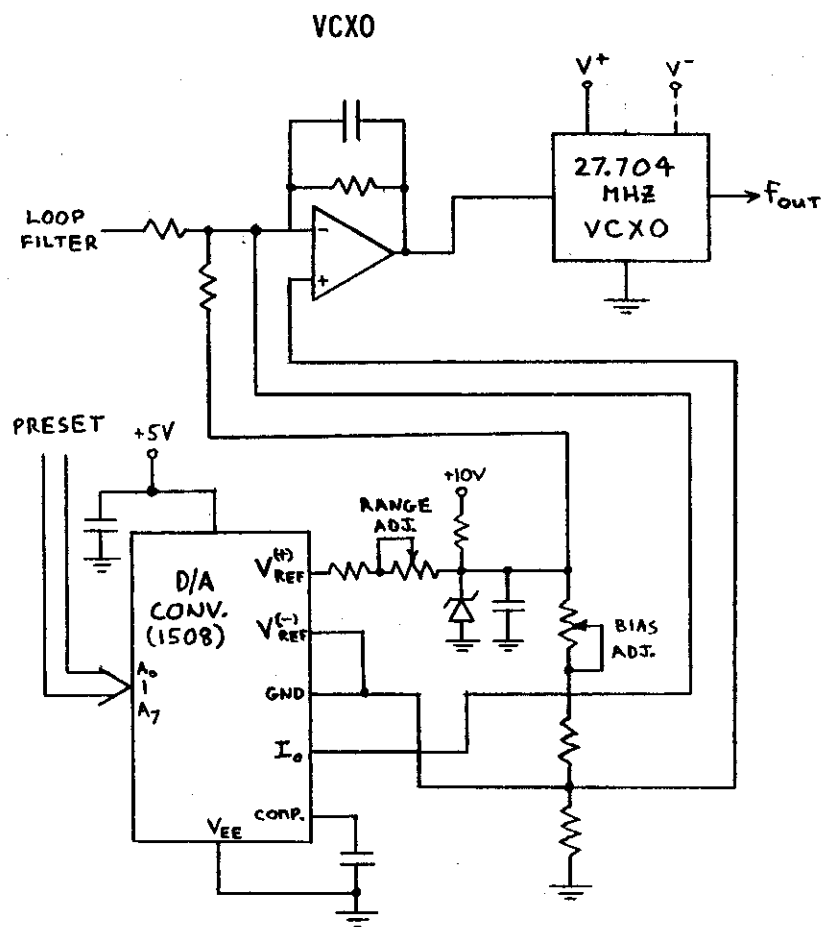
FREQUENCY PLAN ALTERNATIVES





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

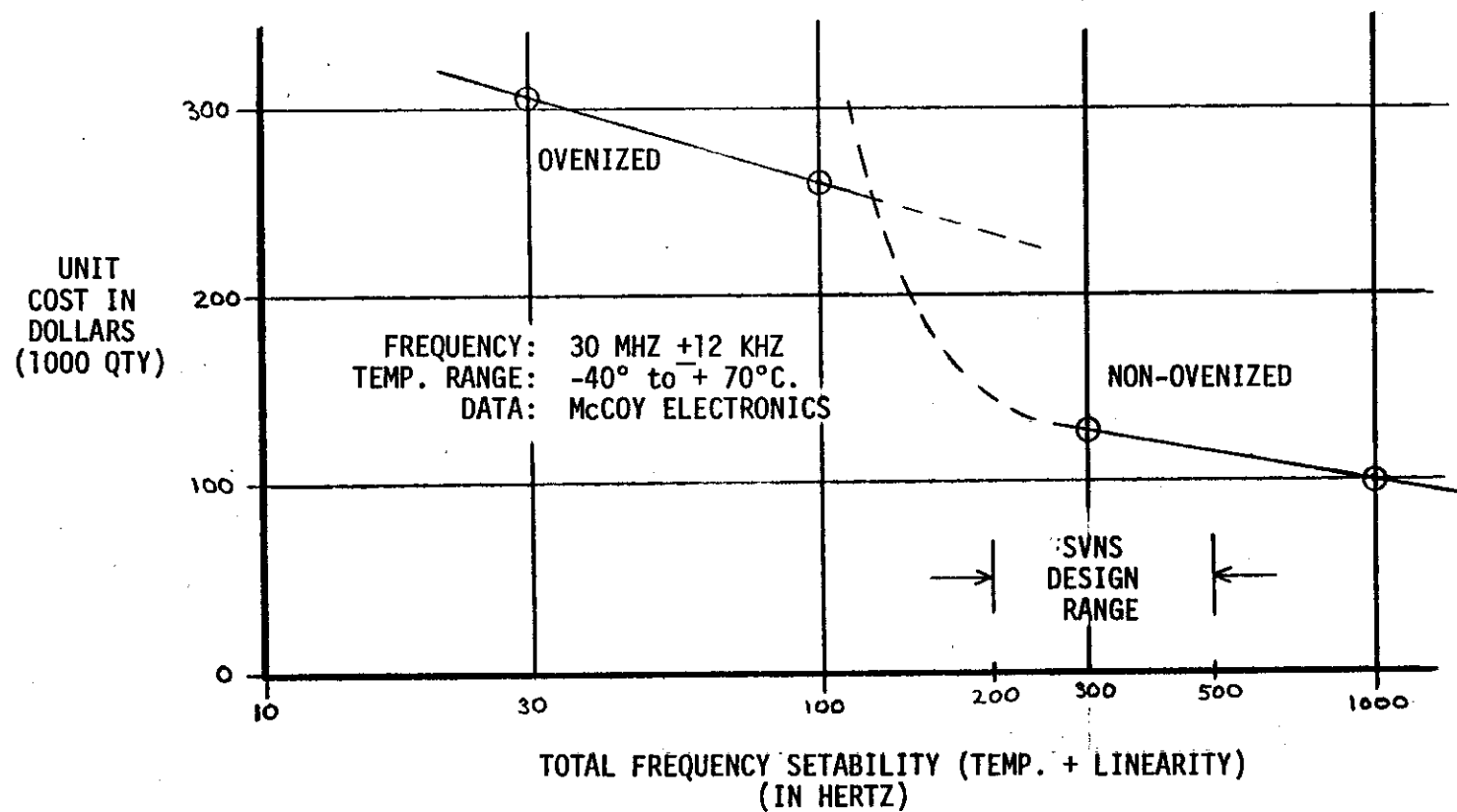
DIGITAL VFO VS. VCXO CIRCUITRY

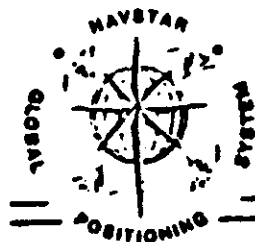




SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY

VCXO COST VS. SETABILITY





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

CARRIER VFO TRADE-OFF RESULTS

- BOTH APPROACHES ALLOW RELATIVELY SIMPLE FREQUENCY PLANS.
 - DIGITAL VFO IMPACTS SYNTHESIZER (EXTRA DIVIDE-BY-FOUR).
- VCXO SUPPORT CIRCUITRY INEXPENSIVE BUT REQUIRES ADJUSTMENT.
- NON-OVENIZED VCXO CAN PROVIDE ADEQUATE "SETABILITY".
- COST (OFF-THE-SHELF):
 - DIGITAL VFO: \$15 + \$6 SUPPORT = \$21
 - VCXO: ? + \$3 SUPPORT = ?
- FINAL DECISION WILL DEPEND UPON REALISTIC, HIGH QUANTITY VCXO COST ESTIMATE.





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

ANTENNA ELEMENT DESIGNS

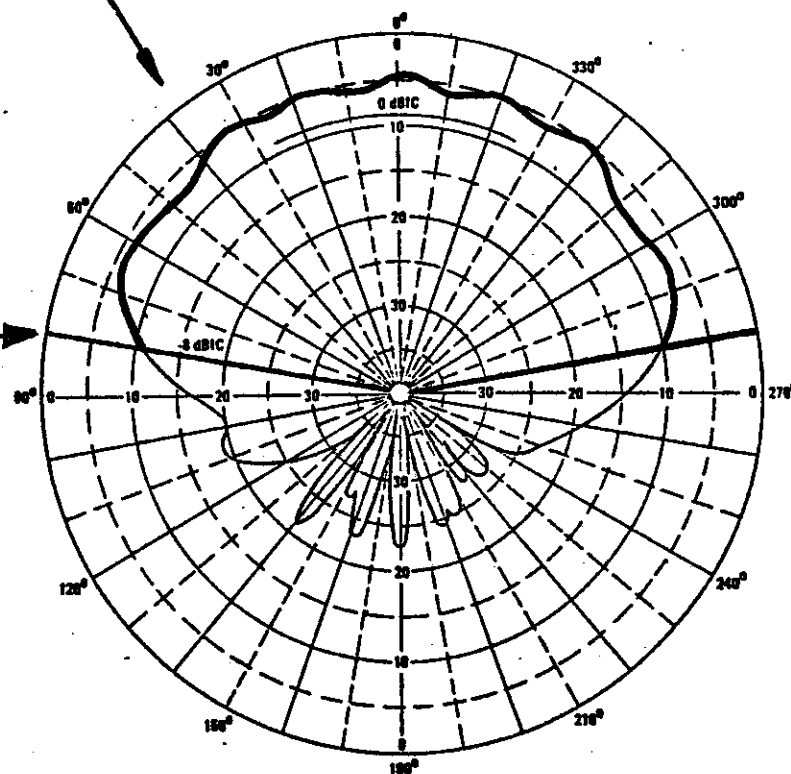
REQUIREMENTS:

- LOW COST
- AUTOMOTIVE MOUNTING
- OMNI PATTERN

- $GAIN \geq -2 \text{ dBIC}$
- $NF_{SYS} \leq 5 \text{ dB}$

DESIGNS:

- VERTICAL STUB
- SINGLE ELEMENT MICROSTRIP
- MICROSTRIP PATCH
- MULTI-ELEMENT MICROSTRIP
- BALL & STEM
- CONICAL SPIRAL
- VERTICAL HELIX





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

POWER SUPPLY

- SERIES REGULATOR

- SIMPLE
- LOW COST
- POOR EFFICIENCY
- SINGLE POLARITY ONLY
- RESTRICTS DESIGN FREEDOM
- LIMITED ISOLATION

- SWITCHING REGULATOR

- MORE COMPLEX
- HIGHER COST
- GOOD EFFICIENCY
- DUAL POLARITY
- IMPROVED DESIGN FREEDOM
- IMPROVED ISOLATION

- CHOICE YET TO BE MADE





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

COST ESTIMATING

- DESIGN HARDWARE WITH STANDARD PARTS WHERE POSSIBLE.
- GENERATE PARTS LIST AND SCHEMATIC.
- ESTIMATE BOARD AREA, POWER CONSUMPTION AND COST.





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

CUSTOM LSI CANDIDATES

- CODE GENERATORS, LATCHES AND CONTROL.
- CODE VFO'S, LATCHES AND CONTROL.
- DIGITAL CARRIER VFO, LATCHES AND PRESET.
- TIMING GENERATOR.





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

CUSTOM LSI TRADE-OFFS

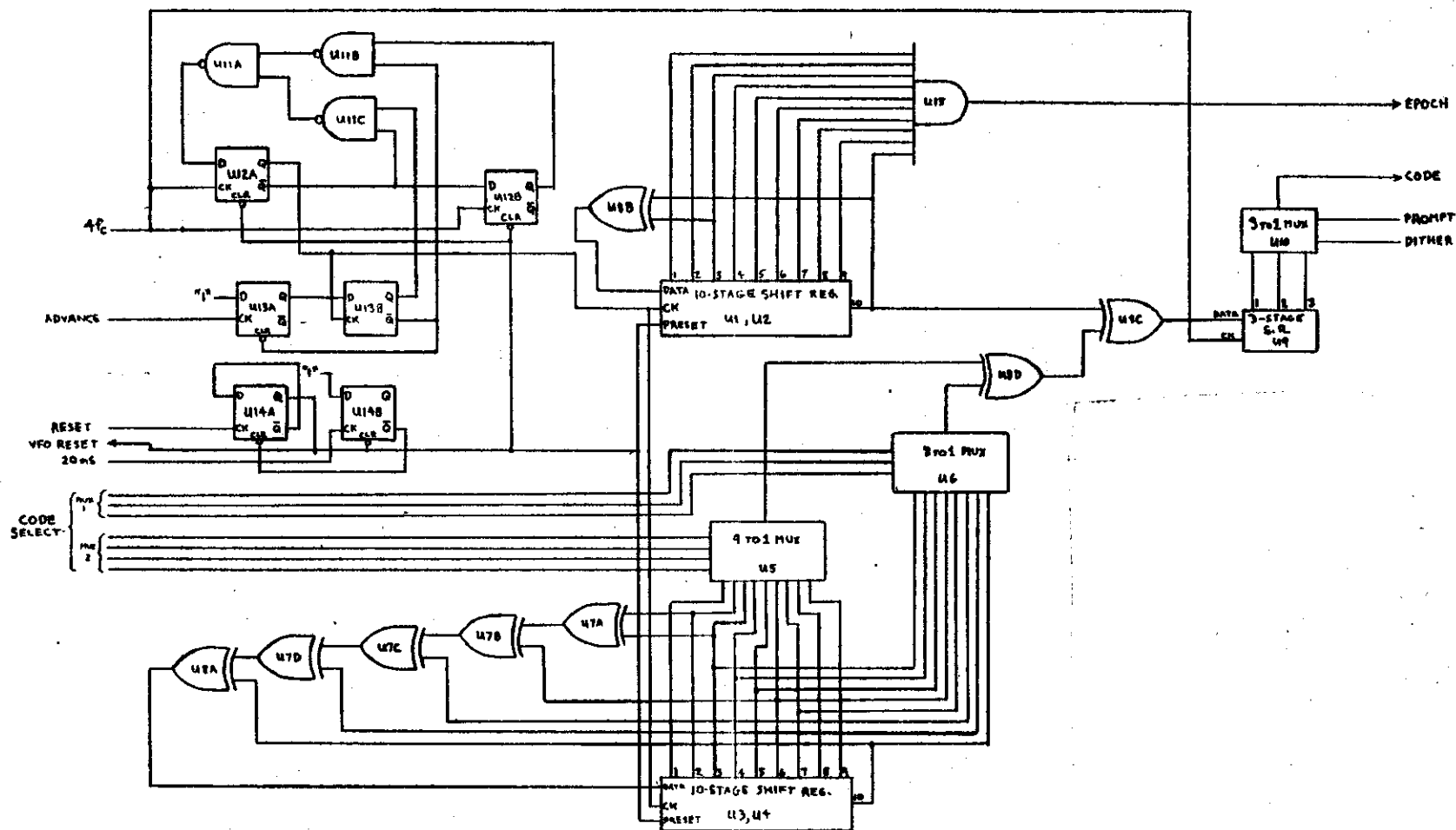
- IDENTIFY CANDIDATE FUNCTIONS.
- FUNCTIONAL DEFINITION (LOGIC DIAGRAMS).
- FUNCTIONAL PARTITIONING (INDIVIDUAL CHIP FUNCTIONS).
 - SPEED REQUIREMENTS
 - LOGIC CELL COUNT
 - CHIP SIZE
- EVALUATE PARTITIONING OPTIONS.





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

CODE GENERATOR LOGIC





SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY

CHIP SIZE COMPARISONS

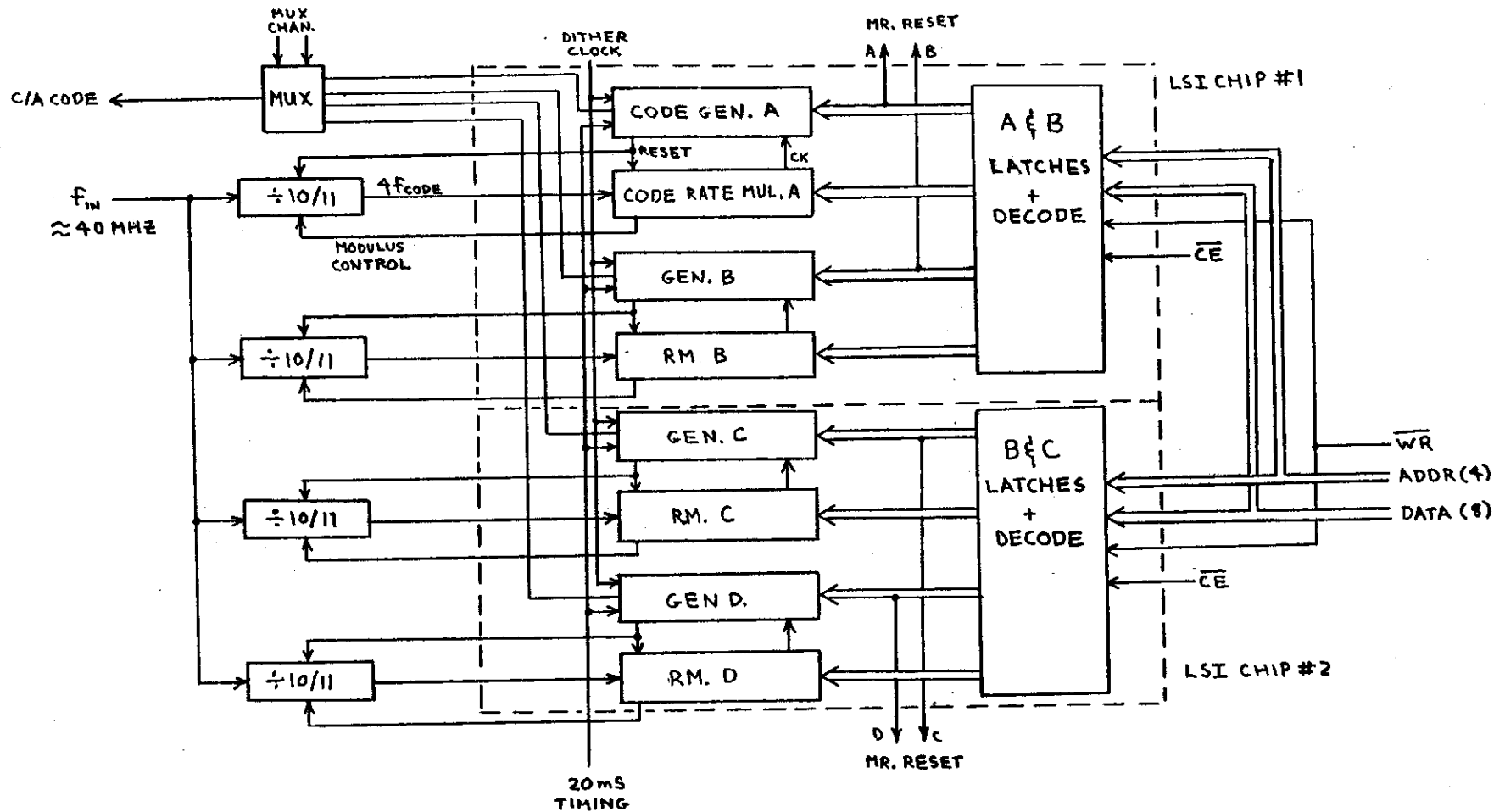
	<u>LARGE CHIP</u>	<u>SMALL CHIP</u>
• FUNCTIONAL CAPABILITIES	HIGH	LOW
• BOARD AREA REQUIREMENT	LOW	HIGH
• INTERCONNECT REQUIREMENTS	LOW	HIGH
• POWER DISSIPATION	HIGH	LOW
• YIELD (COST)	LOW (HIGH)	HIGH (LOW)





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

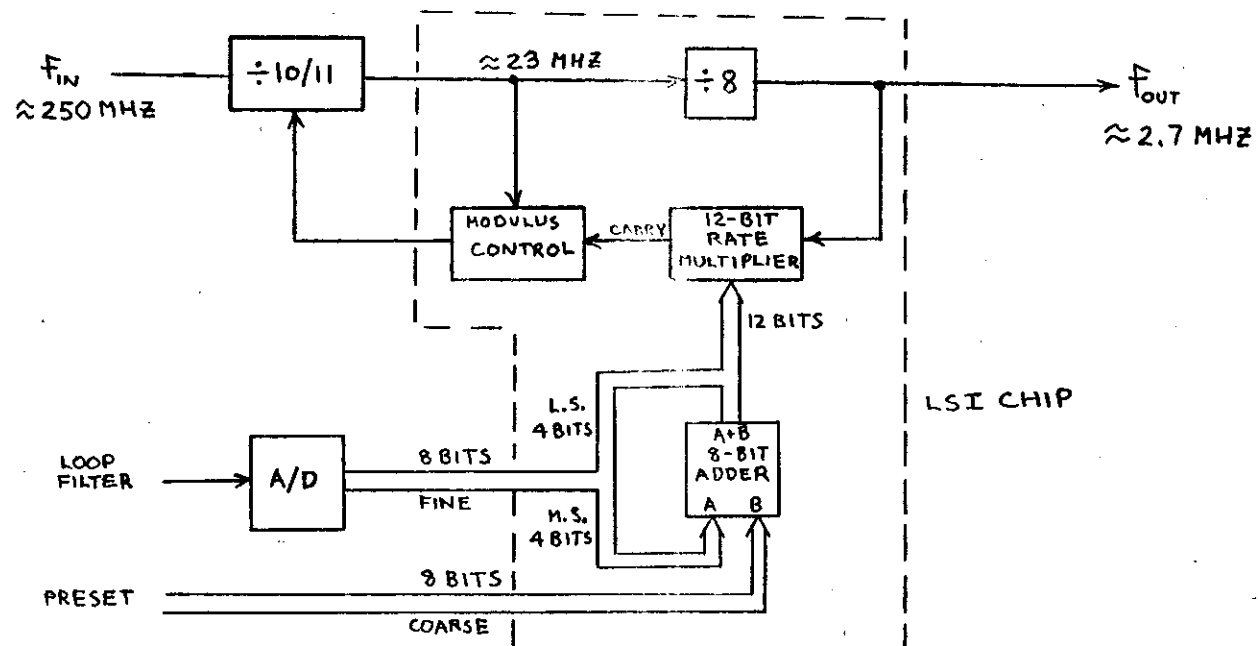
CODE LSI PARTITIONING





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

DIGITAL CARRIER VFO LSI





SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY

PRELIMINARY SIZE AND POWER ESTIMATES

FUNCTION	BOARD AREA	POWER
1. RF PREAMP	6	0.2
2. SYNTHESIZER	9	0.5
3. FREQ STD*	4	0.2
4. RF TRANSLATOR	5	0.4
5. DATA CHANNEL	30	3.0
6. TRACK CHANNEL	30	3.0
7. RCVR CONTROLLER	6	2.1
8. NAV PROCESSOR	40	11.6
9. LOW-POWER TIME SOURCE	2	-
10. POWER SYSTEM**	15	10.5
	147 IN ²	31.5 WATTS

* TCXO, 2" x 2" x 1"

** 50% EFF, 3" x 5" x 1"





**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

FINAL COST DETERMINATION

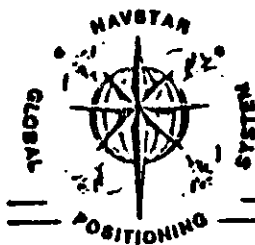
● **ROCKWELL COST ESTIMATE BASED ON AVIONICS PRODUCTION**

- COMPLETE TRADE STUDIES
- COMPLETE CIRCUIT DIAGRAMS
- DEVELOP PARTS LISTS
- DETERMINE PARTS LISTS
- COMPLETE MECHANICAL DESIGN
- DETERMINE MECHANICAL COSTS
- OBTAIN FACTORY LABOR COSTS

● **GM HIGH-VOLUME COST ESTIMATE REQUIRES ASSISTANCE IN**

- DETERMINING HIGH-VOLUME DESIGN TRADE-OFFS
- AUTOMATED TEST AND CIRCUIT ADJUSTMENT
- DETERMINING HIGH-VOLUME PARTS COST
- AUTOMATED ASSEMBLY TECHNIQUES



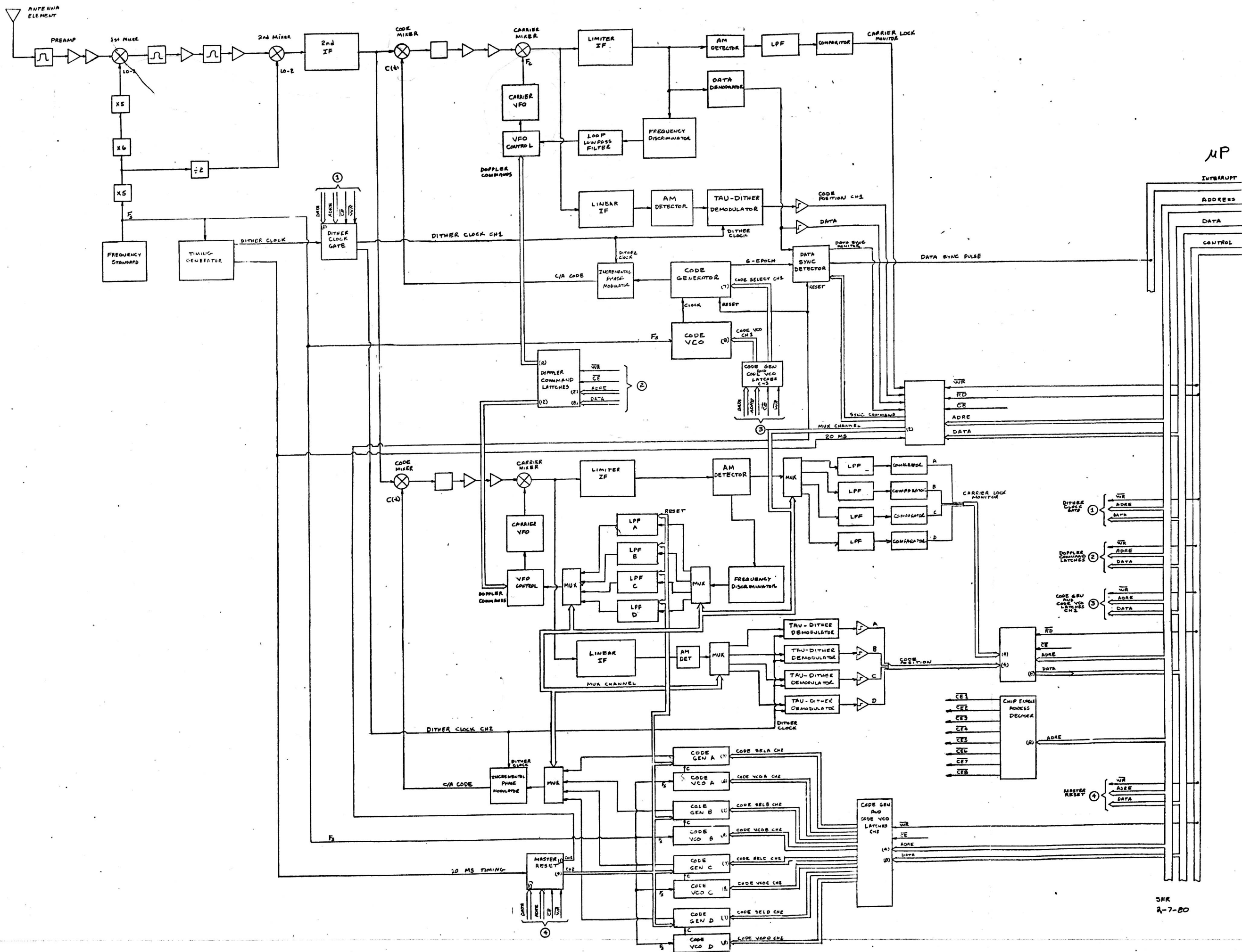


SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

RISK AREAS

- **MEMORY COST**
- **CUSTOM LSI COST & PERFORMANCE**
- **FREQUENCY STANDARD STABILITY**
- **μP THRUPUT**
- **ONE-BIT CODE POSITION DETECTOR**
- **ANTENNA COST**







**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

BASELINE DESIGN COMPLETION

- COMPLETE TRADE-OFF STUDIES
- COMPLETE ELECTRICAL DESIGN AND GENERATE
LIST-OF-MATERIALS
- CHOOSE CANDIDATE MECHANICAL DESIGN
- WORK WITH COLLINS DESIGN-TO-COST SECTION TO COME
UP WITH LOW QUANTITY PRODUCTION COSTS
- WORK WITH GM TO DEVELOP HIGH VOLUME COST ANALYSIS
- COMPLETE RISK ASSESSMENT
- CONDUCT FINAL REVIEW
- DEVELOP FINAL DESIGN DEFINITION





**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

ALTERNATE FUNCTIONAL DESIGN CHOICES

- **DIGITAL CORRELATOR**
- **SINGLE CHANNEL SEQUENTIAL**
- **NONVOLATILE ELECTRONICALLY ERASABLE PROM**
- **LOW-POWER PROCESSOR**
- **SAW RESONATOR OSCILLATOR**
- **DIRECT CONVERSION RECEIVER**
- **MULTIPLEXED CODE GENERATOR**
- **POWER SUPPLY**





SURFACE VEHICLE NAVIGATION SYSTEM FEASIBILITY STUDY

TECHNICAL SUMMARY

- MAJOR EFFORT IS MINIMUM-COST DESIGN APPROACH
- BASELINE DESIGN NOW IN LOW-COST DESIGN CYCLE
- HARDWARE DESIGN NEARING COMPLETION
- MAJOR HARDWARE COST ELEMENTS IDENTIFIED
- ANTENNA SELECTION MADE
- LSI LOOKS FEASIBLE FOR MAJOR PORTIONS OF RECEIVER HARDWARE
- PRELIMINARY SIZE AND POWER ESTIMATES COMPLETED
- FINAL REPORT OUTLINE DEVELOPED
- ENVIRONMENTAL REQUIREMENTS NEED FINALIZATION
- MECHANICAL DESIGN CANDIDATES DEVELOPED AND AWAITING EVALUATION FOR HIGH VOLUME PRODUCTION
- GM HELP NEED FOR HIGH VOLUME FINAL COST DETERMINATION





**SURFACE VEHICLE NAVIGATION SYSTEM
FEASIBILITY STUDY**

FINAL REPORT OUTLINE

- | | |
|----------------------------------|----------------------------------|
| 1, INTRODUCTION | 11, PROCESSOR HARDWARE DESIGN |
| 2, EXECUTIVE SUMMARY | 12, PROCESSOR SOFTWARE DESIGN |
| 3, GPS SYSTEM OVERVIEW | 13, GPS SET POWER SYSTEM |
| 4, SYSTEM DESIGN REQUIREMENTS | 14, MECHANICAL DESIGN |
| 5, SYSTEM DESIGN ISSUES | 15, INTERFACE DEFINITIONS |
| 6, GPS SIGNALS | 16, COST ANALYSIS |
| 7, LOW-COST DESIGN APPROACH | 17, TECHNOLOGY SUMMARY |
| 8, PRELIMINARY SYSTEM DEFINITION | 18, TRADE-OFF STUDY SUMMARY |
| - ANTENNA | 19, SYSTEM SPECIFICATION SUMMARY |
| - RECEIVER | 20, SYSTEM PERFORMANCE SUMMARY |
| - PROCESSOR | 21, PHASE II & III PLANNING |
| - MECHANICAL | 22, APPENDIX |
| 9, ANTENNA DESIGN | |
| 10, RECEIVER DESIGN | |



PERSONNEL TASKS AND MANNING LEVELS

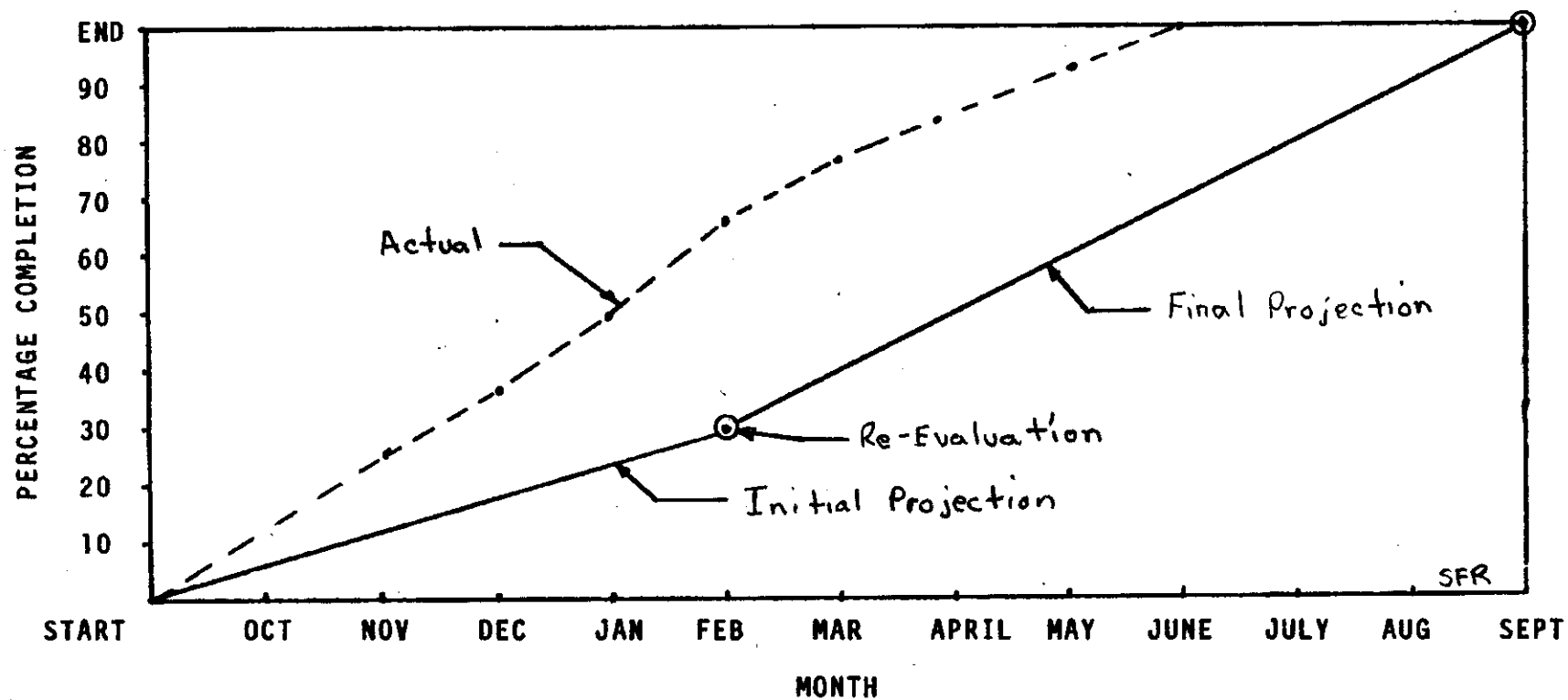
<u>NAME</u>	<u>TASKS</u>	<u>% OF REMAINING EFFORT</u>
S.F. RUSSELL	- PROJECT MANAGER - SYSTEM CONCEPT - TECHNOLOGY - COST ANALYSIS - ANTENNA DESIGN - PHASE II & III PLANNING - FINAL REPORT	21
L.M. NIGRA	- HARDWARE DESIGN - LOW-COST ANALYSIS - TRADE STUDIES - TECHNOLOGY - RECEIVER DESIGN	27
R.W. WALSTROM	- PROCESSOR HARDWARE - PROCESSOR SOFTWARE - COST ANALYSIS - TRADE STUDIES	27
P.L. ROBERTS	- MECHANICAL DESIGN - ENVIRONMENT - LOOKING MODEL	20
R.H. POOL	- SYSTEM CONSULTING	<u>5</u> 100%

SCHEDULE AND MANNING

- PROGRAM COMPLETION RATE

- PERSONNEL TASKS AND MANNING LEVELS

PROGRAM COMPLETION RATE



Planning to
Complete

Internal Letter



Rockwell International

Date: . 21 May 1980

No: .

TO: (Name, Organization, Internal Address)

- . L. E. DeGroot 107-142
- . N. B. Hemesath 124-222
- . R. H. Pool 124-222

FROM: (Name, Organization, Internal Address, Phone)

- . S. F. Russell
- . 124-222
- . X4911

Subject: . SVNS Planning, Schedule, and Cost for Program Completion.

Project planning for the remaining SVNS effort has been completed and reviewed as of 9 May. Enclosed are the data sheets that summarize this effort. Attachment I is the cost summary for 39-0548 and actual work order costs through April. The accounting people have not revised the work order for 39-0548 to reflect the increase in G&A and R&D but all of my planning is based on a reduction in hours. Notice that the dollar reduction is only 13% but, due to higher-than-estimated rates, the actual reduction in effort is 29%. Engineering cost charts showing rate-of-expenditure are included in Attachment II. These will be used to monitor spending rates on the EPs. Attachment III summarizes the hourly charges by month and breaks down the hours into individual work tasks per man. Attachment IV is a master schedule-to-complete showing major tasks. Finally, Attachment V is the group of monthly planning charts that show manning levels and major milestones.

Steve F. Russell

S. F. Russell

SFR/mm

Attachment

ATTACHMENT I

COST SUMMARY AND WORK ORDER COSTS (ACTUALS)

COST SUMMARY

39-0548

	<u>HOURS</u>	<u>DOLLARS</u>	<u>RATE</u>	<u>CH</u>
<u>PRIOR</u>	4679	\$ 137,538	\$ 29.39	1.25
<u>REVISED</u>	3845	119,126	30.98	1.35
<u>ACTUAL</u> (END OF MARCH)	1450.5	51,775	35.69	1.23
<u>REMAINING</u>	1877	67,351	35.69	—

BUDGET DOLLAR REDUCTION: $\frac{119,126}{137,538} \Rightarrow .87$ (13%)

HOURS: STARTED WITH 4679 HRS
 NOW HAVE 3337 HRS

BUDGET HOUR REDUCTION: $\frac{3337}{4679} \Rightarrow .71$ (29%)

WORK ORDER COSTS (ACTUALS)

39-0548

BUDGET: \$ 119,126
ENGR COST (Revised)

MONTH	CURRENT		TO DATE		BUDGET BALANCE	RATE PER HR	OH FACTOR
	HOURS	Dollars	HOURS	Dollars			
OCT	301.2	10,080	301.2	10,080	109,046	33.49	1.15
NOV							
DEC	108.8	5,013	410.	15,093	104,033	46.08	1.65
JAN	245.5	10,916	655.5	26,009	93,117	44.46	1.55
FEB	318.7	10,034	974.2	36,044	83,082	31.48	1.02
MAR	476.3	15,731	1450.5	51,775	67,351	33.05	1.12
APRIL	406.3	13,906	1856.8	65,681	54,255	34.23	1.30
MAY							
JUNE							
JULY							
AUG							
SEPT							

$$\text{AVE RATE [END OF MARCH]} = \frac{51,775}{1450.5} = \$35.69$$

173 HRS/MO

SFR
24 APRIL 1980

WORK ORDER COSTS (ACTUALS)

39-7053

BUDGET: \$29,900
ENGR COST

MONTH	CURRENT		TO DATE		BUDGET BALANCE	RATE PER HR	OH FACTOR
	HOURS	DOLLARS	HOURS	DOLLARS			
OCT	88.5	2,016	88.5	2,016	27,884	22.78	1.15
DEC	105.	3,292	193.5	5,309	24,591	31.35	1.15
JAN	158.5	3,431	352.	8,741	21,159	21.65	0.85
FEB	122.	2,992	474.	11,734	18,166	24.52	1.10
MAR	124.	3,286	598.	15,021	14,879	26.50	1.05
APRIL	135.	3,388	733.	18,409	11,491	25.10	1.15
MAY							
JUNE							
JULY							
AUG							
SEPT							

$$\text{AVE RATE [END OF MARCH]} = \frac{15,021}{598} = \$25.12/\text{HR}$$

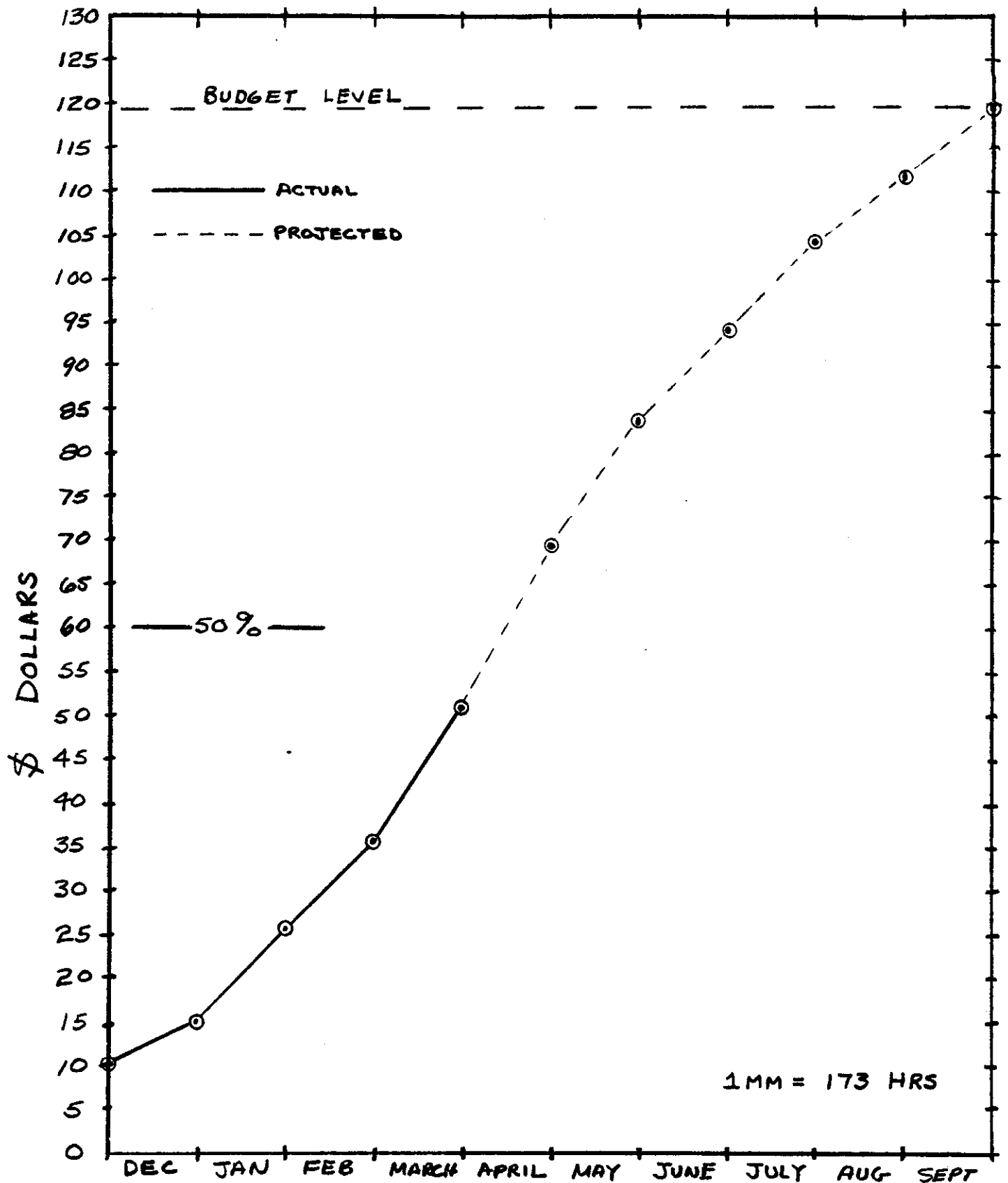
SFR
24 APRIL 1980

ATTACHMENT II

ENGINEERING COST CHARTS

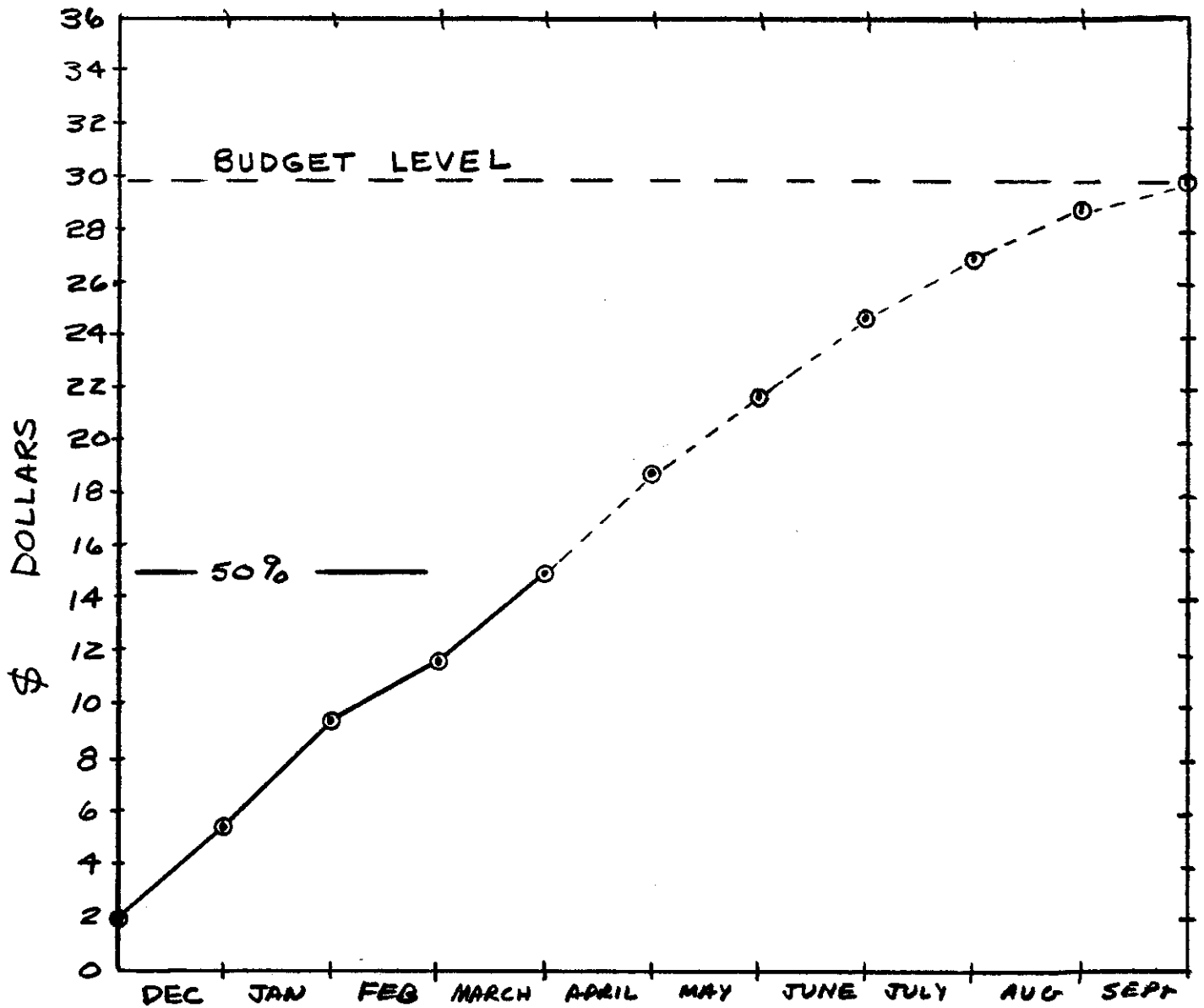
ENGINEERING COST

39-0548



ENGINEERING COST

39-7053



SFR
9 MAY 1980

ATTACHMENT III

HOURLY CHARGES BY MONTH

AND

INDIVIDUAL WORK TASKS

SFR
30 APRIL 1980

Hourly Charges by Month

	MAY	JUNE	JULY	AUG	SEPT	TOTAL
Russell	132	120	54	126	96	528
NIGRA	132	122	100	124	48	526
Walstrom	132	126	50	84	18	410
Roberts	88	82	94	84	60	408
Hemesath	4	10	20	10	8	52
Pool	12	60	46	8	24	150
MAYER						

SVNS WORK
SCHEDULE

SFR
30 APRIL 1980

MAY 1 to SEPT 26

R. W. Walstrom

Task	HRS
Complete Investigation of Processor Chips	52
LSI Design Assistance	10
Preliminary Cost Estimate	15
Develop Software Concept	50
Determine Memory Size (6-13/7-25)	65
Write Draft Report (6-23/7-4)	60
Prepare Hardware Diagrams (7-21/7-25)	30
Write Final Report (8-4/9-2)	120
Final Report Corrections (9-8/9-11)	18
Total	420

SFR
30 APRIL 1980

R.W. Walstrom

Processor

Week	DATE	39-0548	TASKS
27	4-4	31 HRS	—
28	4-11	40 ↓	—
29	4-18	40	—
30	4-25		—
31	5-2	— [12]	PROCESSOR CHIP INVESTIGATION
32	5-9	30	PROCESSOR CHIP INVESTIGATION
33	5-16	30	DEVELOP SOFTWARE CONCEPT (20)
34	5-23	30	PROCESSOR CHIP INVESTIGATION (10)
35	5-30	30	LSI ASSISTANCE (10) SOFTWARE (5)
36	6-6	30	PRELIM COST EST (15) CONCEPT (5)
37	6-13	30	SOFTWARE CONCEPT (25)
38	6-20	30	MEMORY SIZE (5)
39	6-27	30	MEMORY SIZE
40	7-4	30	MEMORY SIZE
41	7-11	0	PREPARE HARDWARE DIAGRAMS
42	7-18	0	WRITE FIRST DRAFT
43	7-25	20	WRITE FIRST DRAFT
44	8-1	20	VACATION
45	8-8	20	VACATION
46	8-15	20	WRITE FINAL REPORT
47	8-22	20	WRITE FINAL REPORT
48	8-29	20	WRITE FINAL REPORT
49	9-5	0	WRITE FINAL REPORT
50	9-12	18	—
51	9-19	0	FINAL REPORT CORRECTIONS
52	9-26	0	—

MAY 132 HRS
JUNE 126 "
JULY 50 "
AUG 84 "
SEPT 18 "

P. L. Roberts

SVNS WORK
SCHEDULE

SFR
30 APRIL 1980

MAY 1 to Sept 26

TASK	HRS
Cost Estimating	50
Heat Analysis	30
Card Area Estimate	10
Trade Off Analysis of designs (6-9/6-20)	40
Write Draft Report (6-23/7-11)	30
EMI Shield Design for Card (6-23/7-4)	20
Design Looking Model (7-7/8-4)	70
Write Final Report (8-4/8-22)	60
Model Shop coordination (8-11/8-29)	20
Build Looking Model (9-2/9-12)	60
Contingency and other	30
Total 420 HRS	

P. L. Roberts

Mechanical DesignSFR
30 APRIL 1980

WEEK	DATE	39-0548	TASKS
27	4-4	—	
28	4-11	—	
29	4-18	—	BOX DESIGN
30	4-25	—	BOX DESIGN
31	5-2	20 Hrs	COST ESTIMATING (10)
32	5-9	20 ↓	COST ESTIMATING (10)
33	5-16	20	COST ESTIMATING (10)
34	5-23	20	COST ESTIMATING
35	5-30	20	HEAT ANALYSIS (10) CARD AREA ESTIMATE (10)
36	6-6	20	HEAT ANALYSIS
37	6-13	20	TRADE OFF ANALYSIS
38	6-20	20	TRADE OFF ANALYSIS
39	6-27	22	EMI SHIELD DESIGN (12) WRITE DRAFT REPORT (10)
40	7-4	18	EMI SHIELD DESIGN (8) WRITE DRAFT REPORT (10)
41	7-11	20	WRITE DRAFT REPORT (10) DESIGN LOOKING MODEL (10)
42	7-18	20	DESIGN LOOKING MODEL
43	7-25	20	DESIGN LOOKING MODEL
44	8-1	20	DESIGN LOOKING MODEL
45	8-8	20	FINAL REPORT WRITING
46	8-15	30	FINAL REPORT WRITING (25) MODEL SHOP COORDINATION (5)
47	8-22	20	FINAL REPORT WRITING (15) MODEL SHOP COORDINATION (5)
48	8-29	10	MODEL SHOP COORDINATION
49	9-5	30	BUILD LOOKING MODEL
50	9-12	30	BUILD LOOKING MODEL
51	9-19	0	—
52	9-26	0	—

CONTINGENCY
& OTHER
(30)

MAY	88	Hrs
JUNE	82	"
JULY	94	"
AUG	84	"
SEPT	60	"

SYNS WORK
SCHEDULE

SFR
30 APRIL 1980

L. M. Nigra

MAY 1 TO SEPT 26

TASK	HRS
Complete Schematics and Parts Lists for the Baseline Design (5-1/5-9)	42
LSI Design and Cost Estimates (5-12/5-23)	40
Design-to-Cost Analysis (5-19/5-23)	20
Family Tree Input to GM (5-26/6-6)	40
Power Requirements (6-2/6-6)	12
Alternate Designs (6-9/6-20)	60
Write Draft Report (6-23/7-4)	64
TRADE OFF ANALYSIS (7-14/8-1)	70
RISK ANALYSIS (7-24/7-25)	10
Write Final Report (8-4/8-29)	120
Final Report Review (9-2/9-8)	24
Final Corrections (9-8/9-11)	24
Total	526

SFR
30 APRIL 1980

L. M. NIGRA

Electrical Design

Week	DATE	39-7053	39-0548	TASK
27	4-4	—	—	—
28	4-11	—	—	—
29	4-18	—	—	—
30	4-25	—	—	—
31	5-2	— [12]	—	FINAL BASELINE DESIGN COMPLETE PARTS LISTS (10)
32	5-9	30	—	COMPLETE PARTS LISTS
33	5-16	30	—	LSI DESIGN & COST
34	5-23	30	—	LSI DESIGN & COST (10) DESIGN-TO-COST ANALYSIS (20)
35	5-30	30	—	FAMILY TREE
36	6-6	22	—	FAMILY TREE (10) POWER REQUIREMENTS (12)
37	6-13	30	—	ALTERNATE DESIGNS
38	6-20	30	—	" "
39	6-27	34	—	WRITE DRAFT REPORT
40	7-4	25	5	" " "
41	7-11	0	0	VACATION
42	7-18	25	5	TRADE-OFF ANALYSIS
43	7-25	25	5	TRADE-OFF ANALYSIS (20) RISK ANALYSIS (10)
44	8-1	15	5	TRADE-OFF ANALYSIS
45	8-8	25	5	WRITE FINAL REPORT
46	8-15	25	5	" " "
47	8-22	25	5	" " "
48	8-29	25	5	" " "
49	9-5	20	4	FINAL REPORT REVIEW
50	9-12	24	0	FINAL CORRECTIONS
51	9-19	0	0	—
52	9-26	0	0	—

182 44

MAY	132	HRS
JUNE	122	"
JULY	100	"
AUG	124	"
SEPT	48	"

SFR

30 APRIL 1980

S. F. Russell

SYSTEM

week	DATE	39-0548	TASK
27	4-4	6	_____
28	4-11	0	_____
29	4-18	22	_____
30	4-25	26	_____
31	5-2	30	SCHEDULE PLANNING
32	5-9	30	PREPARE DRAFT OUTLINE
33	5-16	30	ANTENNA DESIGN
34	5-23	30	PREPARE DRAFT OUTLINE
35	5-30	30	L-BAND DESIGN
36	6-6	30	PREPARE DRAFT OUTLINE
37	6-13	30	DESIGN-TO-COST ANALYSIS
38	6-20	30	OUTLINE REVIEW
39	6-27	30	POWER INTERRUPT ANALYSIS
40	7-4	0	REVISE OUTLINE
41	7-11	0	POWER REQUIREMENTS
42	7-18	0	ALTERNATE DESIGNS
43	7-25	30	ALTERNATE DESIGNS
44	8-1	30	WRITE FIRST DRAFT
45	8-8	30	WRITE FIRST DRAFT
46	8-15	30	VACATION
47	8-22	30	VACATION
48	8-29	30	VACATION
49	9-5	30	RISK ANALYSIS
50	9-12	26	PHASE II & III PLANNING
51	9-19	10	PHASE II & III PLANNING
52	9-26	22	WRITE FINAL REPORT
			WRITE FINAL REPORT
			WRITE FINAL REPORT
			WRITE FINAL REPORT
			FINAL REPORT REVIEW
			FINAL REPORT CORRECTIONS
			ASSIST FINAL REPORT TYPING
			REVIEW AND SUBMIT TO PUBS

MAY	132	HES
JUNE	120	"
JULY	54	"
AUG	126	"
SEPT	96	"

SFR
1 MAY 1980

SVNS WORK
SCHEDULE

MAY 1 to SEPT 26

R.H. Pool

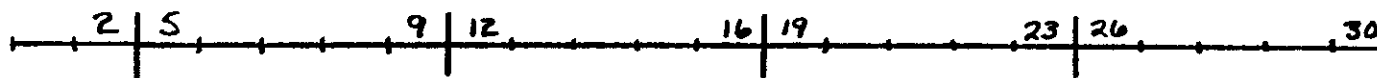
Task	HOURS
Outline Review (5-19/5-22)	12
Alternate Designs (6-2/6-27)	60
Review First Draft (7-14/7-25)	26
Phase II & III Planning (7-21/7-31)	20
GM VISIT (8-1)	8
FINAL REPORT REVIEW (9-2/9-8)	24
Total	150 HRS

ATTACHMENT IV

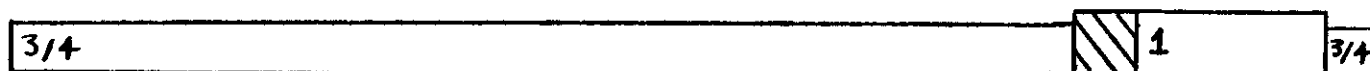
MASTER SCHEDULE-TO-COMPLETE

ATTACHMENT V

MONTHLY PLANNING CHARTS

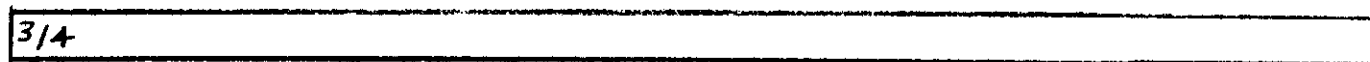
MAY

Russell



132 HRS

Nigra



132 HRS

Walstrom



132 HRS

Roberts



88 HRS

Pool



12 HRS

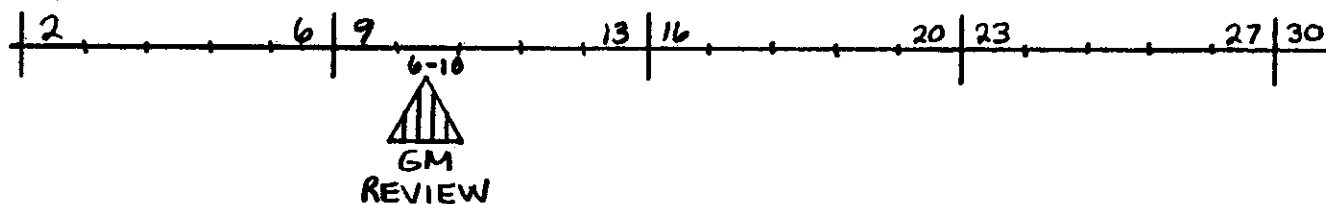
Mayer

Hemesath

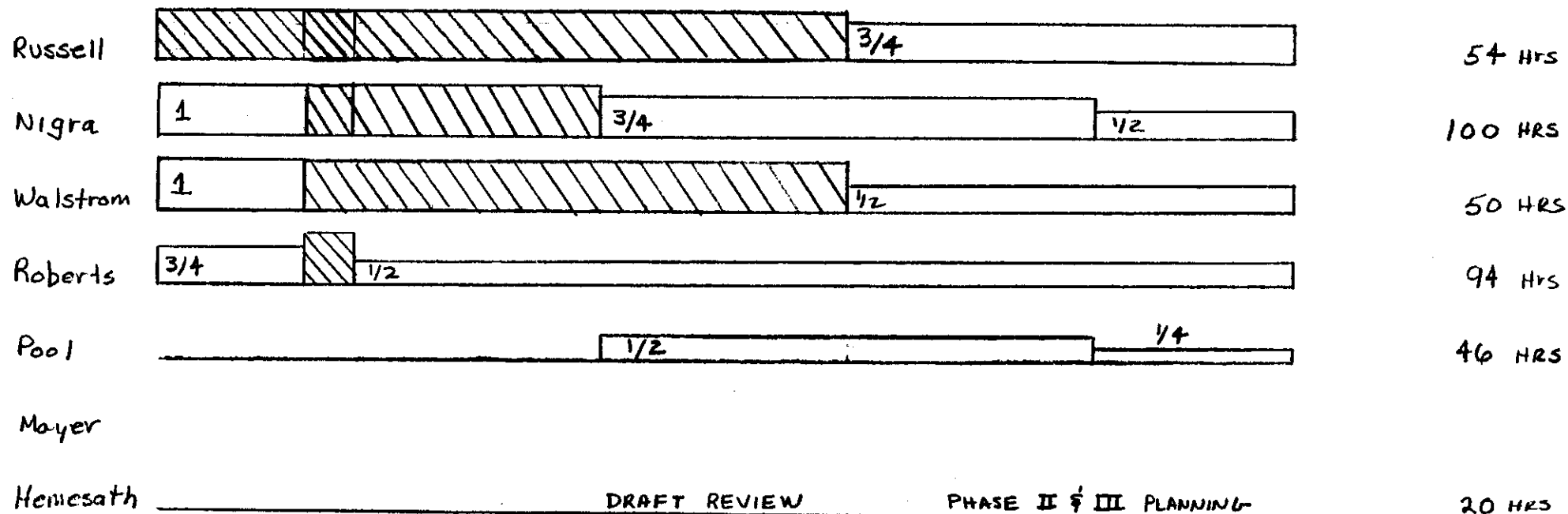
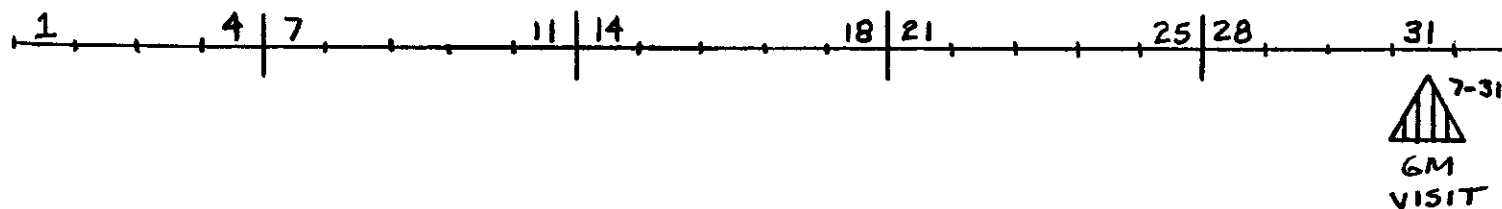


4 HRS

JUNE

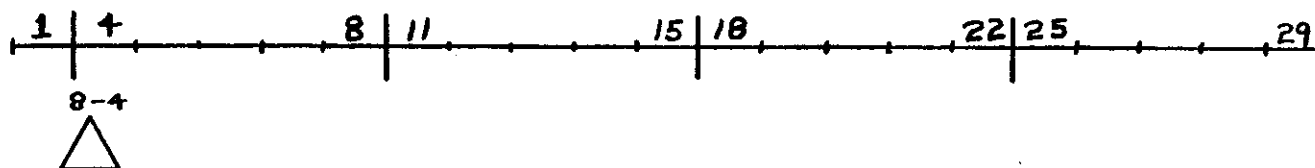


Russell	<div><div>3/4</div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><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JULY

SFL
5-2-80

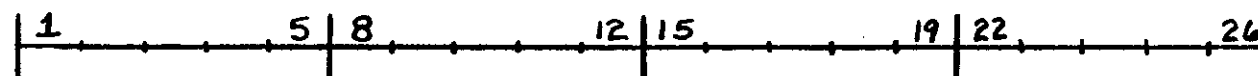
AUG



Russell	$\frac{3}{4}$	126 HRS
Nigra	$\frac{1}{2}$ $\frac{3}{4}$	124 HRS
Walstrom	$\frac{1}{2}$	84 HRS
Roberts	$\frac{1}{2}$ $\frac{3}{4}$ $\frac{1}{2}$ $\frac{1}{4}$	84 HRS
Pool	1	8 HRS
Mayer		
Hemesath	GM VISIT	10 HRS

SEPT

168 HRS



△ FINAL TYPING △

△ FINAL CORRECTIONS △

△ FINAL REVIEW △

9-2
△
SECOND DRAFT
COMPLETED

9-12
△
LOOKING MODEL
FINISHED

9-26
△
SUBMIT REPORT
TO PUBS

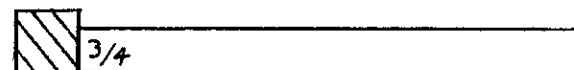
△ BUILD LOOKING MODEL △

Russell



96 HRS

Nigra



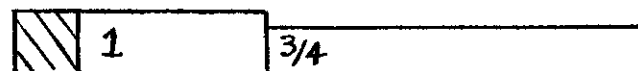
48 HRS

Walstrom



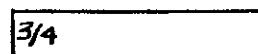
18 HRS

Roberts



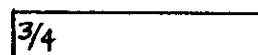
60 HRS

POOL



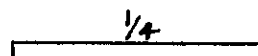
24 HRS

MAYER



24 HRS

HEMESATH



8 HRS

278 HRS